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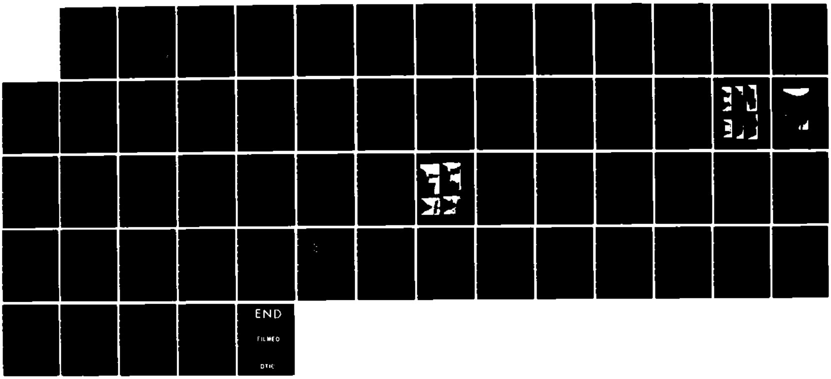

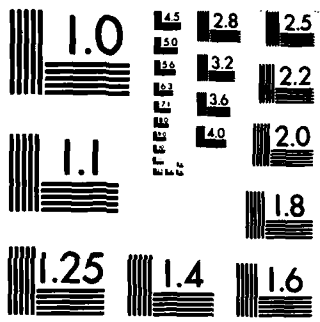
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POWERING PREDICTIONS AND PROPELLER DISK WAKE SURVEY DATA FOR THE USNS HAYES T-AGOR 16 REPRESENTED BY MODEL 5285

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

POWERING PREDICTIONS AND PROPELLER DISK WAKE SURVEY DATA FOR THE USNS HAYES T-AGOR 16 REPRESENTED BY MODEL 5285

by

Bruce Crook

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SHIP PERFORMANCE DEPARTMENT
DEPARTMENTAL REPORT

JANUARY 1985

DTNSRDC/SPD-072-14

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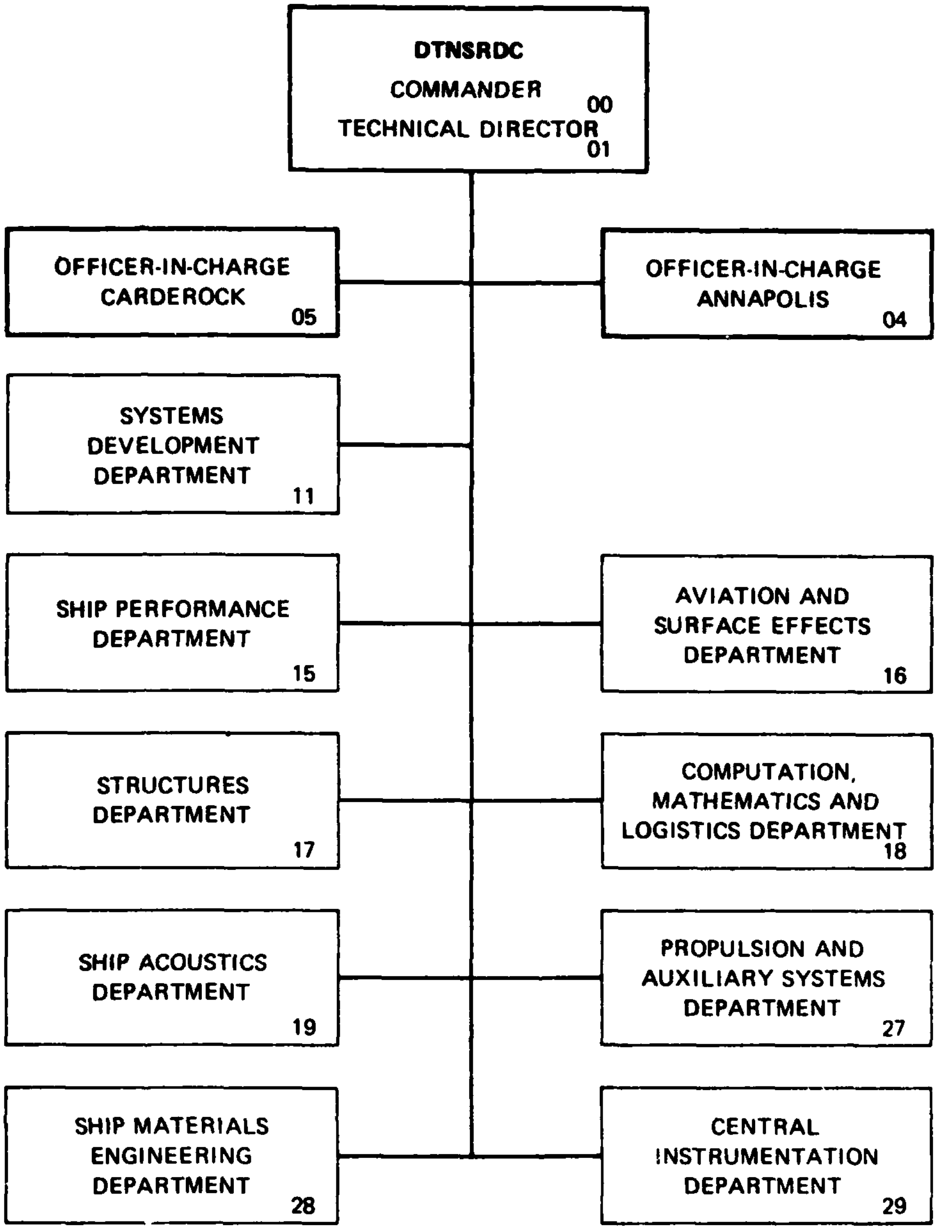

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T-AGOR 16
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Experiments were conducted on a model representing the USNS HAYES T-AGOR 16 to determine the feasibility of replacing the Mobile Noise Barge (MONOB) with the USNS HAYES. Resistance, propulsion, towing and wake survey experiments were performed on Model 5285 with a bow foil. Results of the propulsion experiments showed the USNS HAYES T-AGOR 16 attaining a 12.4 knot speed at a delivered power of 2,200 horsepower (1,641 kilowatt) with the design propeller pitch. Towing predictions showed the HAYES could tow an

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array with a resistance of 29,000 pounds (129,000 newtons) at 10 knots and resistance of 9,000 pounds (40,000 newtons) at 12 knots. The wake survey experiments provided data to enable the propeller designer to design a fixed pitch propeller that will replace the existing controllable pitch propeller.

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NOTATION

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
A_N	COS COEF	The cosine coefficient of the N^{th} harmonic*
B_N	SIN COEF	The sine coefficient of the N^{th} harmonic*
D	---	Propeller diameter
J_V	---	Apparent advance coefficient $J_V = \frac{V}{nD}$ (dimensionless)
N	N	Harmonic number
n	---	Propeller revolutions
r/R or x	Radius or RAD	Distance (r) from the propeller axis expressed as a ratio of the propeller radius (R)
V	V	Actual model or ship velocity
$V_b(x,\theta)$	---	Resultant inflow velocity to blade for a given point
$\bar{V}_b(x)$	---	Mean resultant inflow velocity to blade for a given radius
$V_r(x,\theta)$	VR	Radial component of the fluid velocity for a given point (positive toward the shaft centerline)
$\bar{V}_r(x)$	---	Mean radial velocity component for a given radius
$V_r(x,\theta)/V$	VR/V	Radial velocity component ratio for a given point
$\bar{V}_r(x)/V$	VRBAR	Mean radial velocity component ratio for a given radius

*See last page of notations.

NOTATION

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
$V_t(x,\theta)$	VT	Tangential component of the fluid velocity for a given point (positive in a counter-clockwise direction looking forward)
$\bar{V}_t(x)$	---	Mean tangential velocity velocity component for a given radius
$V_t(x,\theta)/V$	VT/V	Tangential velocity component ratio for a given point
$\bar{V}_t(x)/V$	VTBAR	Mean tangential velocity component ratio for a given radius
$(\tilde{V}_t(x)/V)_N$	AMPLITUDE	Amplitude (B_N for single screw symmetric; C_N otherwise) of Nth harmonic of the tangential velocity component ratio for a given radius*
$V_x(x,\theta)$	VX	Longitudinal (normal to the plane of survey) component of the fluid velocity for a given point (positive in the astern direction)
$\bar{V}_x(x)$	---	Mean longitudinal velocity component for a given radius
$V_x(x,\theta)/V$	VX/V	Longitudinal velocity component ratio for a given point
$\bar{V}_x(x)/V$	VXBAR	Mean Longitudinal velocity component ratio for a given radius
$(\tilde{V}_x(x)/V)_N$	AMPLITUDE	Amplitude (A_N for single crew symmetric; C_N otherwise) of Nth harmonic of the longitudinal velocity component ratio for a given radius*
ϕ_N	PHASE ANGLE	Phase Angle of Nth harmonic*

*See last page of notations.

NOTATION

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
$1 - w(x)$	1 - WX	Volumetric mean velocity ratio from the hub to a given radius

$$1 - w(r/R) = \left[\frac{2 \cdot \int_{r_{hub}/R}^{r/R} (\bar{V}_{x_c}(x)/V \cdot x \cdot dx}{(r/R)^2 - (r_{hub}/R)^2} \right]$$

$$\text{where } \bar{V}_{x_c}(x)/V = \int_0^{2\pi} \left[\frac{V_{x_c}(x,\theta)}{2\pi V} \right] d\theta$$

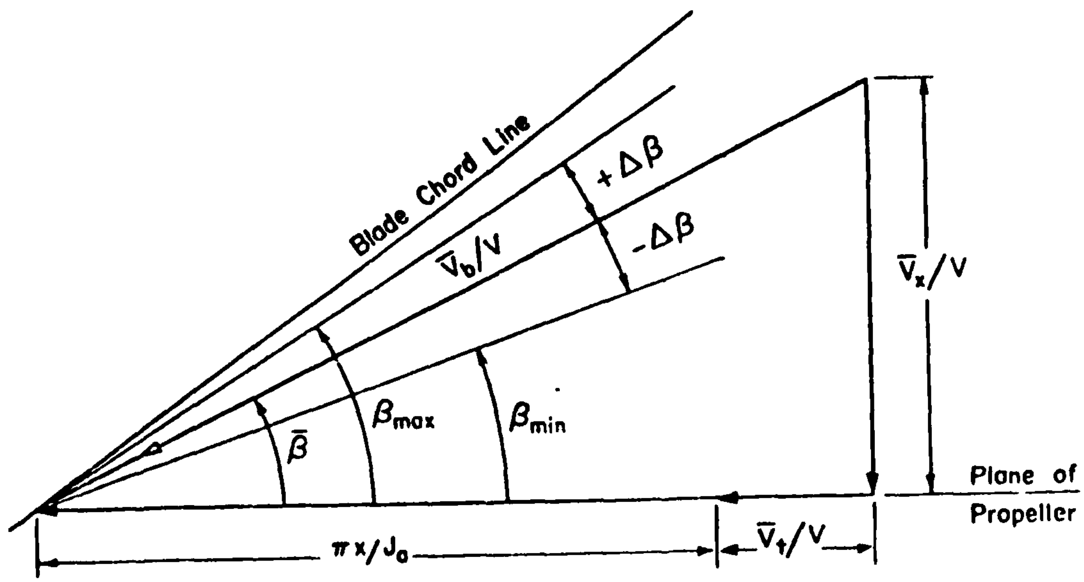
$$\text{and } V_{x_c}(x,\theta)/V) = (V_x(x,\theta)/V) - (V_t(x,\theta)/V) \tan(\beta(x,\theta))$$

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
$1 - w_v(x)$	1 - WVX	Volumetric mean velocity ratio from the hub to a given ratio (without the tangential correction)

$$1 - w(r/R) = \left[\frac{2 \cdot \int_{r_{hub}/R}^{r/R} (\bar{V}_x(x)/V) \cdot x \cdot dx}{(r/R)^2 - (r_{hub}/R)^2} \right]$$

NOTATION

CONVENTIONAL SYMBOL	SYMBOL APPEARING ON PLOTS	DEFINITION
$\beta(x,\Theta)$	---	Advance angle in degrees for a given point
$\bar{\beta}(x)$	BBAR	Mean advance angle in degrees for a given radius
$+\Delta\beta$	BPOS	Variation of the maximum advance angle from the mean for a given radius
$-\Delta\beta$	BNEG	Variation of the minimum advance angle from the mean for a given radius
Θ	Angle in Degrees	Position angle (angular coordinate) in degrees



VELOCITY DIAGRAM OF BETA ANGLES

NOTATION

*The harmonic amplitudes of any circumferential velocity distribution $f(\theta)$ are the coefficients of the Fourier Series:

$$f(\theta) = A_o + \sum_{N=1}^{N} A_N \cos(N\theta) + \sum_{N=1}^{N} B_N \sin(N\theta)$$

$$= A_o + \sum_{N=1}^{N} C_N \sin(N\theta + \phi_N)$$

ABSTRACT

Experiments were conducted on a model representing the ~~USNS~~ HAYES, ~~T-AGOR 16 to determine~~ the feasibility of replacing the Mobile Noise Barge (MONOB) with the USNS HAYES. Resistance, propulsion, towing, and wake survey experiments were performed on Model 5285 with a bow foil. Results of the propulsion experiments showed the USNS HAYES T-AGOR 16 attaining a 12.4 knot speed at a delivered power of 2,200 horsepower (1,641 kilowatt) with the design propeller pitch. Towing predictions showed the HAYES could tow an array with a resistance of 29,000 pounds (129,000 newtons) at 10 knots and resistance of 9,000 pounds (40,000 newtons) at 12 knots. The wake survey experiments provided data to enable the propeller designer to design a fixed pitch propeller that will replace the existing controllable pitch propeller.

ADMINISTRATIVE INFORMATION

The Naval Sea Systems Command (NAVSEA), PMS-383, authorized and funded this work in accordance with Work Request Number 12001 dated August 1983. The work was performed by the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under DTNSRDC work unit number 1170-441.

INTRODUCTION

The USNS HAYES T-AGOR 16 is an unconventional catamaran hull and is the first catamaran employed for oceanographic research. This vessel, a floating laboratory, provides a stable, quiet, self-sufficient, and maneuverable platform for obtaining oceanographic data and working with a submersible. Processing information on board can be accomplished at three different speed conditions: cruising, normal operation from 5 to 15 knots; creeping, underway at 2 to 4 knots; and quiet operation, ship dead in the water.

The catamaran hulls were laid down 12 November 1969 at Todd Shipyard, Seattle, Washington and launched 2 July 1970. The main propulsion machinery, geared diesels, are rated at 5,400 horsepower (4,027 kilowatt) and operate two controllable pitch propellers for speeds up to 15 knots with a 6,000 mile (11,112 kilometer) range at 13.5 knots. An auxiliary 165 horsepower (123 kilowatt) diesel is fitted in each hull to provide for creeping speeds of 2 to 4 knots. The hull separation and the controllable pitch propellers provide a high degree of maneuverability eliminating the need for bow thrusters.

An investigation was undertaken to determine the feasibility of replacing the Mobile Noise Barge (MONOB) with the HAYES. MONOB is used for determining

acoustical signatures of various marine vehicles. The Naval Sea Systems Command (NAVSEA) requested the David W. Taylor Naval Ship R & D Center (DTNSRDC) to perform model experiments and full-scale trials in order to provide information on the suitability of the HAYES as the MONOB replacement vehicle. The model experiments conducted provide the following information on the USNS HAYES when at a 21.77 foot (6.64 meter) draft:

1. Powering characteristics,
2. Predicted obtainable speed at 2200 horsepower (1640 kilowatt),
3. Maximum tow rope pull during towing conditions, and
4. Wake data for a fixed pitch propeller design.

The results of the model experiments are presented in this report. Full-scale trial results of the USNS HAYES are published in a separate report.[1]

MODEL DESCRIPTION

In 1973, DTNSRDC initiated a model experimental program to evaluate design alternatives for reducing the seakeeping motions of the HAYES[2,3]. Two identical ship models were constructed for this experimental program. Model 5283 was used for seaworthiness experiments and Model 5285 was used for powering and wake survey experiments. Both of these models were constructed from NAVSHIPS Lines and Body Plan 845-4416 791 Revision A to a linear scale ratio of 16.892. The best DTNSRDC stock propellers available (4253 and 4254) had a 12.10 foot (3.69 meter) diameter while the propeller diameter on the HAYES was 12.00 foot (3.66 meter). The rudders, rudder shoe, rudder foot, and shafting were constructed and installed from NAVSHIPS Rudder, Steering Gear and Propeller Guard Drawing 800-2641062. Bilge keels were also installed as part of the basic HAYES configuration. A bow foil with a 2.0 foot (0.61 meter) chord and a 12 foot (3.66 meter) span using an EPH section was installed at Station 4 with a zero degree (0 radian) attack angle (parallel with the baseline). Figure 1 presents the abbreviated lines plan for the HAYES and Figure 2 presents the bow foil location and shape. The fitting room photographs of Model 5285 representing the HAYES are presented in Figures 3 and 4.

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[1] References are listed in page 9.

Originally, the HAYES had a design waterline draft of 18.50 feet (5.64 meter) resulting in a length of 220 feet (67.1 meter) and 3,000 ton (3,048 metric ton) displacement for both hulls. However, NAVSEA requested that all experiments in 1973 be conducted at a mean draft of 19 feet (5.791 meters) trimmed 3 feet (0.914 meters) by the stern corresponding to a 3,140 ton (3,190 metric ton) displacement. Since 1973, the draft of the HAYES has increased to 21.77 ft (6.64 meter) even keel corresponding to a 3,780 ton (3,840 metric ton) displacement.

EXPERIMENTAL PROCEDURE

Resistance

Model 5285 was ballasted to a heavy displacement corresponding full-scale to 3,780 tons (3,840 metric tons) at a 21.77 foot (6.64 meter) draft even keel above the baseline. Appendages on the model included the bow foil, bilge keels, rudders and rudder shoes. A series of turbulence stimulating studs, 0.125 inches (3.2 millimeter) in diameter, were placed on the bow of each demihull to insure turbulent flow along the hull. During the resistance, propulsion and towing experiments, the model was towed from a yoke attached to the towing carriage and connected to each demihull through a small force gage to a tow post. The model was towed along the shaft centerline and was free to trim and sink (heave) depending on the towing speed. The measurement of resistance occurred simultaneously by both the block gages and the gravity dynamometer on the towing carriage.

Propulsion

During the propulsion experiments, the model propellers rotated outward with the left hand propeller 4254 on the port hull and the right hand propeller 4253 on the starboard hull. The propeller thrust and torque were measured in each hull by a 20 pound (88.96 newtons), 20 pound-inch (2.26 newton-meter) transmission dynamometer. The carriage speed and each propeller's shaft speed were measured by magnetic pickups counting either 360 or 60 toothed gears, respectively. The powering experiments were conducted using a correlation allowance (C_A) of 0.0005 and the ITTC ship-model correlation line for smooth, deep salt water at a temperature of 59° Fahrenheit (15° celsius). The still air drag is not included in the powering predictions presented in this report. Bow

and stern sinkage or rise data were obtained for each data spot during the resistance and propulsion experiments.

Wake Survey

The wake survey experiment was conducted on the port demihull of Model 5285. The rudder and rudder shoe were removed and a fairing piece was added to return the hull baseline to a smooth, continuous line. A new pitot tube rake of six five-hole pitot tubes (3 on each side of the propeller shaft) was used. Two sets of five differential pressure gages measured differential pressures in the propeller plane. The new pitot tube rake consisted of six, five-hole hemispherical head pitot tubes having four static holes 0.89 inch (2.26 centimeter) aft of the head. A stepping motor rotated the rake to different angular positions. The propeller plane is normal to the shaft certerline at a point 1.39 feet (0.42 meter) forward of Station 18 or 23.48 feet (7.15 meter) full-scale forward of the after perpendicular. An angle indicator recorded the angular position. The angles are defined with zero being at the top of the propeller disk along the demihull centerline with increasing angles being measured counter-clockwise when looking forward. Data points were taken every four degrees with finer increments in areas behind the demihull centerline, at the top and bottom positions, bilge keel and bow foil regions. The pitot tubes had been previously calibrated for yaw, pitch and roll in air by the Aviation and Surface Effects Department. A description of the use, calibration, and constants derived for the five-hole pitot tubes is presented in Reference 3. Differential pressures between each outer hole and the center hole of the pitot tube were integrated over a five second period by the computer for each data point. The carriage or model speed, rake angular location and ten differential pressure gage voltages comprised one data point for one pitot tube. Data for two pitot tubes were collected simultaneously and stored on a nine track tape.

The first phase of the data analysis consists of converting the pressure data into a velocity components in the tangential $V_t(x,\theta)$, radial $V_r(x,\theta)$, and longitudinal $V_x(x,\theta)$ directions and nondimensionalized into three velocity component ratios by the free stream velocity. The free stream velocity (towing speed) for this wake survey was 2.43 knots or 4.10 feet per second (1.25 meter per second) which corresponds to a full-scale speed of 10 knots. Interpolation of the velocity component ratios in the radial and circumferential directions

was made. This process yielded interpolated data every 2.5 degrees for the six experimental radii and eight interpolated radii. The mean longitudinal, tangential and radial velocity component ratios; the volumetric mean wake; and the mean and extreme values of the advance angles were computed and are presented in this report. Harmonic analyses of the circumferential distributions of the longitudinal and tangential velocity component ratios were computed for the experimental data. The harmonic content was determined by Fourier series analysis. The results of the harmonic analyses are presented as amplitudes and phase angles of a sine series.

The shape of the pitot tube rake was such that the rake could possibly change the hull trim or roll while the model was being towed. To insure the proper trim without roll throughout the wake survey experiments, the model was towed at a model speed corresponding to the HAYES ship speed of 10 knots while free to assume the correct trim without roll with the rake in the zero (vertical) position. The model was then locked in this trim condition throughout the wake survey experiment.

DATA ACCURACY

Repeatability of model resistance and propulsion experimental results at DTNRDC for surface ships for model speeds above 2 knots (for HAYES is 8.2 knots, full-scale) is ± 1.5 percent for effective power and ± 2.5 percent for delivered power. The accuracy of the pressure transducer system is approximately plus or minus three hundredths of an inch for a water pressure (7.5 pascal). The accuracy of the entire velocity survey is estimated to be ± 2 percent in longitudinal velocity component ratio (V_x/V) except in locations where steep velocity gradients occur. In these areas, such as behind a shaft strut, the accuracy is significantly less.

PRESENTATION OF RESULTS

The model experimental program and conditions of the USNS HAYES that were represented in the experiments are presented in Table 1. The body plan, profile and waterline plan are presented in Figure 1 with the bow foil details given in Figure 2. Fitting room photographs of the HAYES as represented by Model 5285 are presented in Figures 3 and 4. The model propeller open-water characteristic curves are presented in Figure 5 for Propellers 4253 and 4254. Resistance and propulsion data are presented in curves and tables of effective

power, P_E, delivered power, P_D, revolutions per minute, RPM and propulsive coefficients.

The HAYES powering predictions, with propellers 4253 and 4254 representing a 116 percent of design pitch, at a heavy displacement condition are presented in Figure 6 and Table 2. Sinkage and change of level curves are presented in Figure 7. Predictions of powering requirements during simulated straight line towing operations are presented in Figure 8 and Table 3 for full-scale speeds of 10 and 12 knots towing an array with 2256 pounds (10,035 newtons) of added resistance.

Full-scale trial data of the HAYES, at a 3,634 ton (3,692 metric-ton) displacement in brackish water corresponding to a 21.77 foot (6.635 meter) draft even keel at propeller pitches of 111 and 118 percent of design pitch, are presented in Table 4. A comparison of the model powering predictions and HAYES standardization trial data is presented in Figure 9 and Table 5.

The wake survey radii, propeller radius, and hub radius are shown in the abbreviated port demihull body plan along with the bilge keel and bow foil locations in Figure 10. Figure 11 presents the wake survey radii, propeller radius, and hub radius on an abbreviated port demihull profile lines plan. The fitting room photographs of the wake survey rake are shown in Figure 12. The shape and size of this wake survey rake required a small alteration to the aft end of the rudder fairing as seen in Figure 12.

The HAYES full-scale propeller disk is 12.0 feet (3.66 meter) in diameter with a hub diameter of 3.28 feet (1.00 meter). The measurement radii were 2.01 feet (0.61 meter), 2.68 feet (0.82 meter), 3.68 feet (1.12 meter), 4.68 feet (1.43 meter), 5.69 feet (1.73 meter) and 6.69 feet (2.04 meter) full-scale. Expressed as propeller radius ratios (r/R: r = measurement radius, R = propeller radius), they are 0.334, 0.446, 0.613, 0.780, 0.948 and 1.115. A sketch of the wake survey rake arrangement is presented in Figure 13. The circumferential distributions for the longitudinal, tangential, and radial velocity component ratios are presented in graphical form in Figures 14 through 19. Tabulated velocity component ratios at the experimental radii are presented in Table 6. Figure 20 presents a vector diagram showing the velocity magnitudes in the propeller plane without a propeller operating. A contour plot showing the longitudinal component iso-wake ($w = 1 - V_x/V$) is presented in Figure 21.

The radial distributions of the circumferential mean velocities and advance angles are plotted in Figures 22 and 23. Sixteen harmonics were calculated from the six experimental radii and eight interpolated radii. The circumferential mean longitudinal (VXBAR), tangential (VTBAR), and radial (VRBAR) velocity component ratios and the volumetric mean wake velocity ratio $(1-W_X)$ are presented in Table 7. The calculated mean advance angle (βBAR) and the maximum variations thereof, (βPOS) and (βNEG), are also shown in Table 7. The advance angles were calculated using an advance coefficient, J_V, of 0.703. A diagram showing the relationship between the longitudinal and tangential velocity vectors, the advance coefficients, and the advance angles is presented on page xi. The amplitudes and phase angles for the longitudinal velocity component ratios are presented in Table 8 for the measured and interpolated radii. Table 9 presents the amplitude and phase angles for the tangential velocity component ratios for the experimental and interpolated radii.

DISCUSSION

Model 5285, representing HAYES, shows an increase in power requirements due to the increased draft and displacement from reported data by Murray[2]. Previously at 13 knots, Model 5285 required 2,320 horsepower (1,730 kilowatt) Model 5285 now requires 2,580 horsepower (1,920 kilowatt) at 13 knots for a 640 ton (650 metric ton) ship change and a 3 foot (0.914 meter) trim change. The model predictions with the 116% propeller pitch and full-scale trial data using the propeller pitches of 111% and 118% compare quite well with each other. Average correlation allowances (C_A) of 0.00075 for the 111% propeller pitch and 0.00085 for the 118% propeller pitch are required to obtain agreement between the delivered power measured during the full-scale trial and that predicted from model experiments.

When comparing wake survey data to previous experimental results, major differences in the measured velocities between the previous Experiment 15 and the Experiment 20 wake survey can be attributed to the speed, draft, displacement, and trim differences between the two experiments. Experiments 21 and 22, short wake surveys with two tubes (r/R = 0.789 and 1.115), were conducted to determine the effects of trim, draft, displacement, and speed. Experiment 21 with the model trimmed by stern showed a reduced velocity between 80 and 100 degrees at both radii due to the bilge keel vortices along the buttock lines as

to the increased draft and displacement from reported data by Murray[2]. Previously at 13 knots, Model 5285 required 2,320 horsepower (1,730 kilowatt) Model 5285 now requires 2,580 horsepower (1,920 kilowatt) at 13 knots for a 640 ton (650 metric ton) ship change and a 3 foot (0.914 meter) trim change. The model predictions with the 116% propeller pitch and full-scale trial data using the propeller pitches of 111% and 118% compare quite well with each other. Average correlation allowances (C_A) of 0.00075 for the 111% propeller pitch and 0.00085 for the 118% propeller pitch are required to obtain agreement between the delivered power measured during the full-scale trial and that predicted from model experiments.

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CONCLUSIONS

Results of the model powering and wake survey experiments for the USNS HAYES show the USNS HAYES meeting the requirements to replace the MOBILE Noise Barge (MONOB). A speed of 12.4 knots can be obtained by the HAYES at 2,200 horsepower (1,641 kilowatt) and 97.5 revolutions per minute. At 10 knots, the HAYES will operate at the same power while towing a simulated array having a drag of 29,000 pounds (129,000 newtons). Data from the wake survey experiments will be used to design a fixed pitch propeller to replace the existing controllable pitch propeller.

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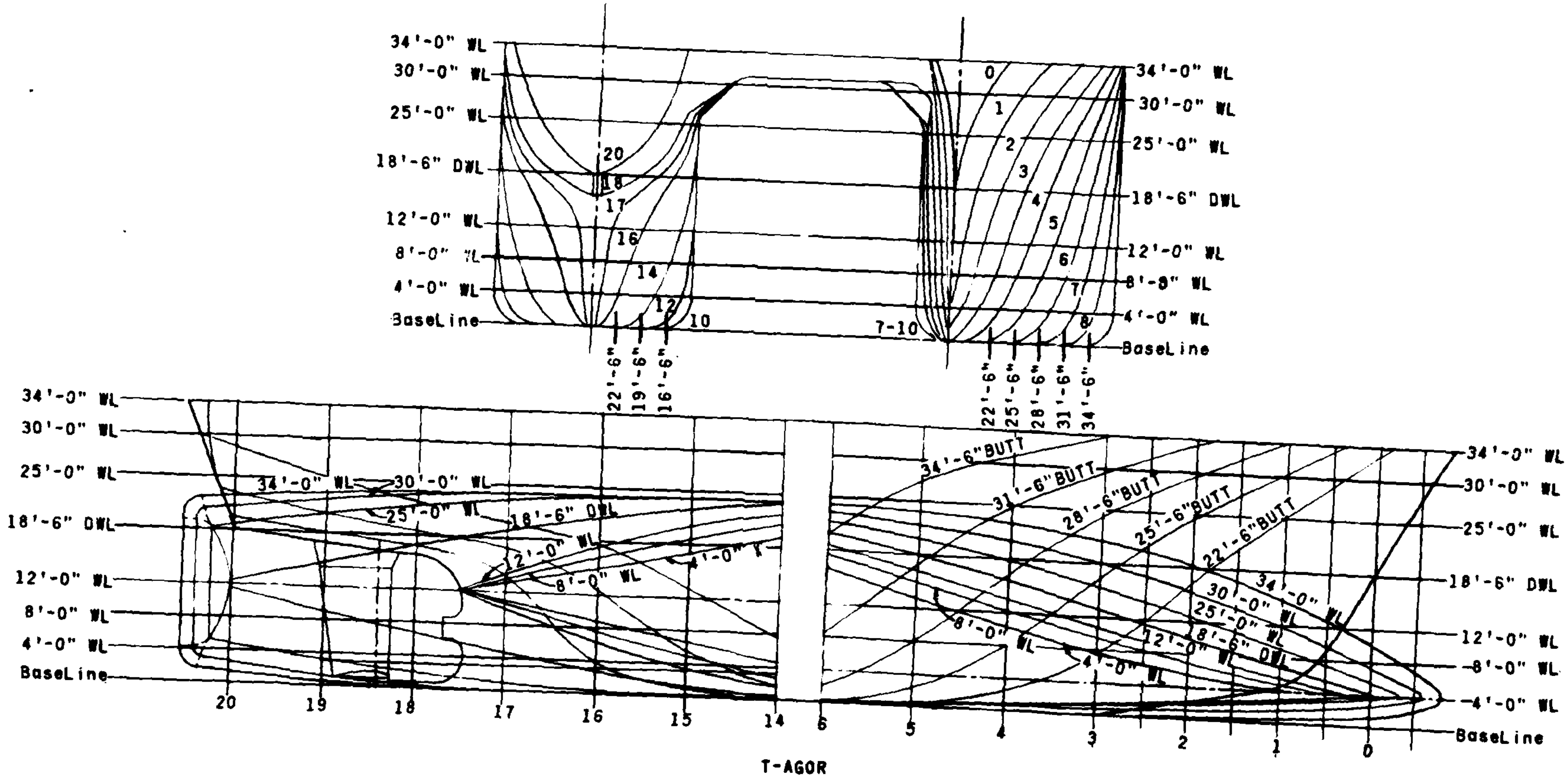
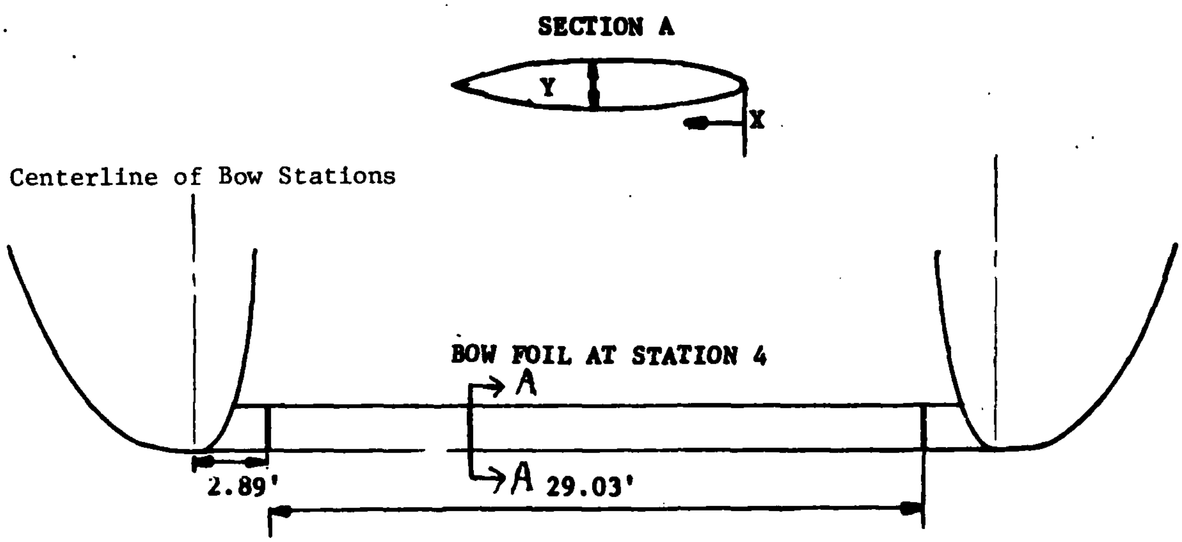


Figure 1 - USNS HAYES T-AGOR 16 Abbreviated Ship Lines Without Bow Foil



BOW FOIL LOCATION AND SHAPE

Section A	
SHIP	FEET
X	Y
12.00	0
11.40	0.60
10.80	0.86
9.60	1.30
8.40	1.64
7.19	1.86
6.00	1.98
4.80	2.00
3.60	1.90
2.39	1.68
1.20	1.28
0.48	0.84
0.17	0.60
0.11	0.42
0.06	0.30

Figure 2 - USNS HAYES T-AGOR 16 Bow Foil Location and Shape

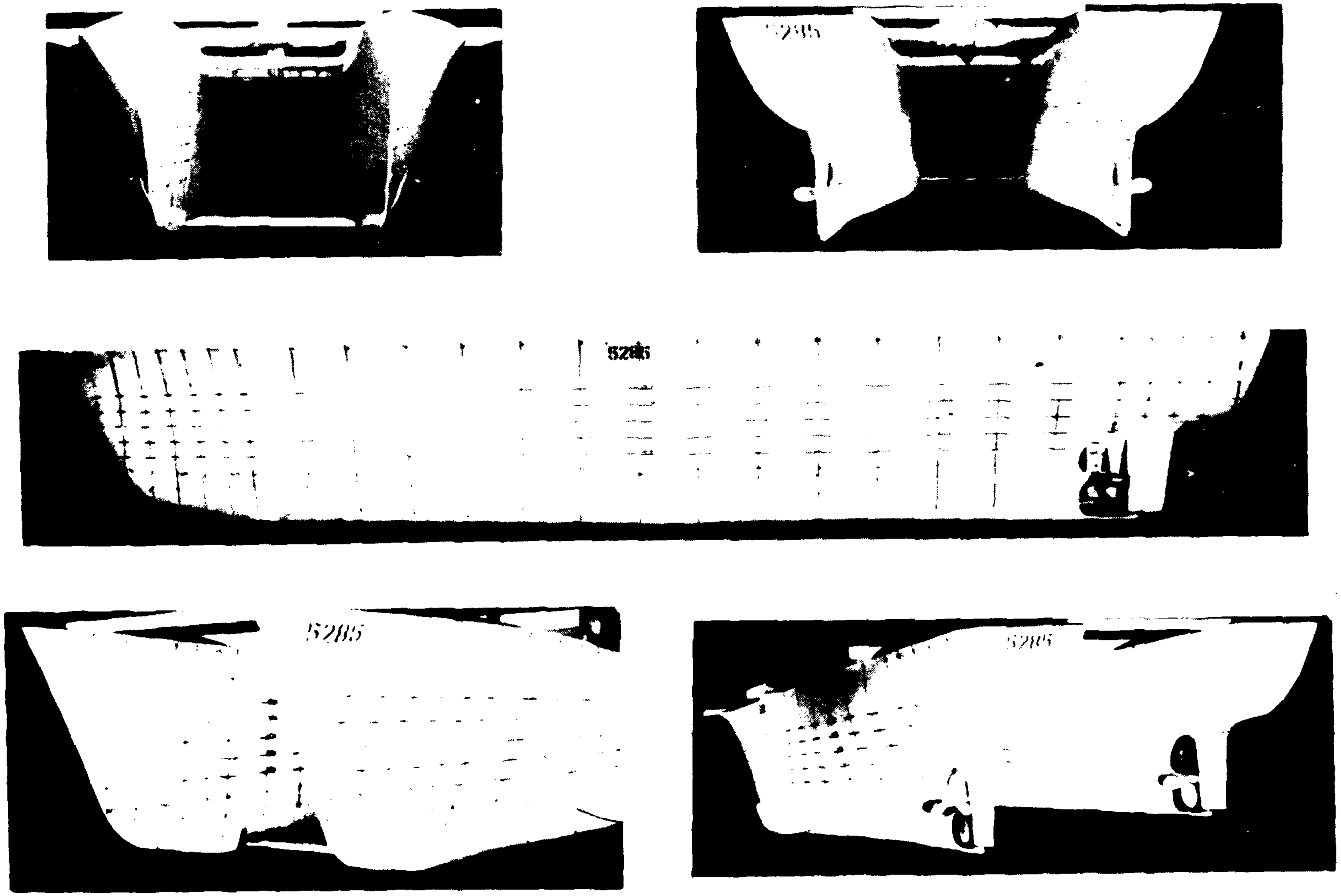


Figure 3 - Fitting Room Photographs of USNS HAYES T-AGOR 16 with Bow Foil
as Represented by Model 5285

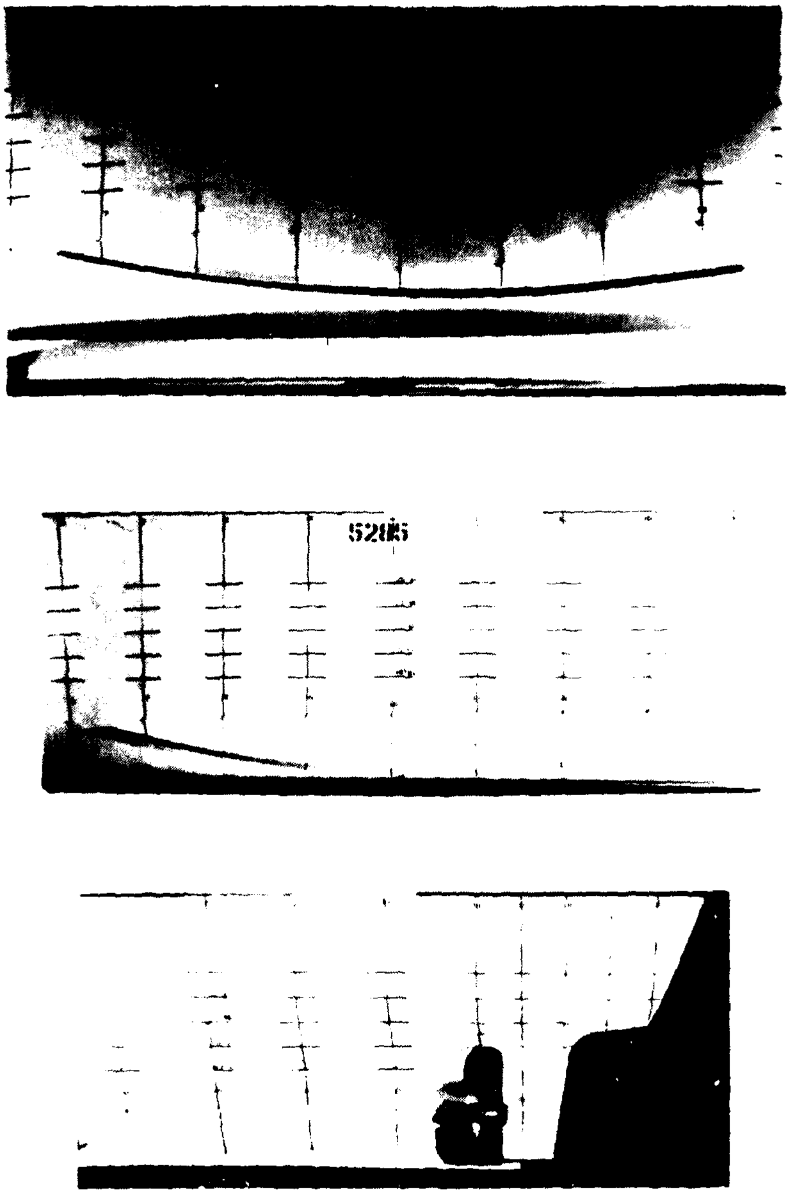


Figure 4 - Fitting Room Photographs of USNS HAYES T-AGOR 16 Bilge Keel and Stern Regions as Represented by Model 5285

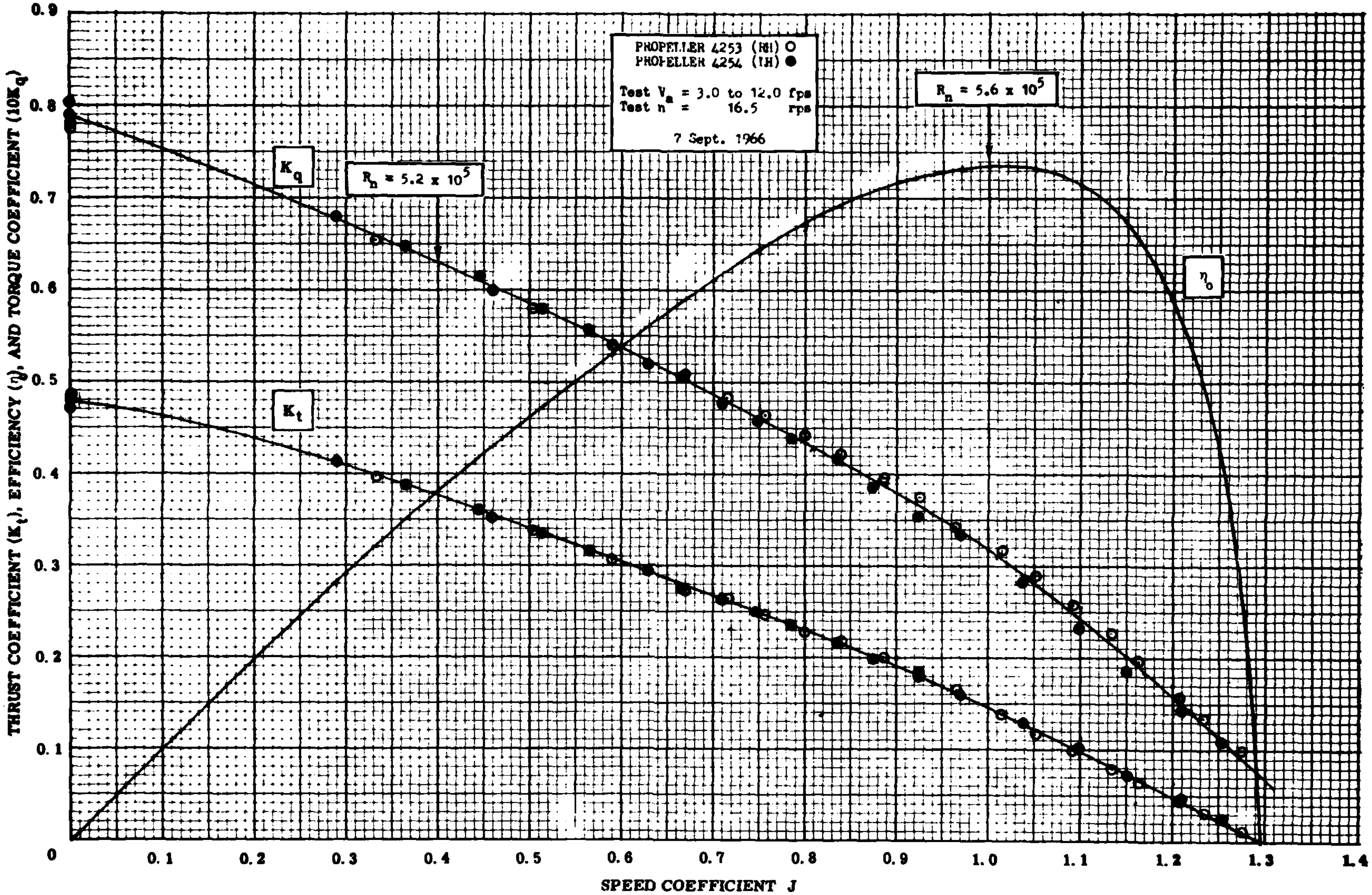


Figure 5 - Open Water Characteristics Curves for Model Propellers 4253 and 4254

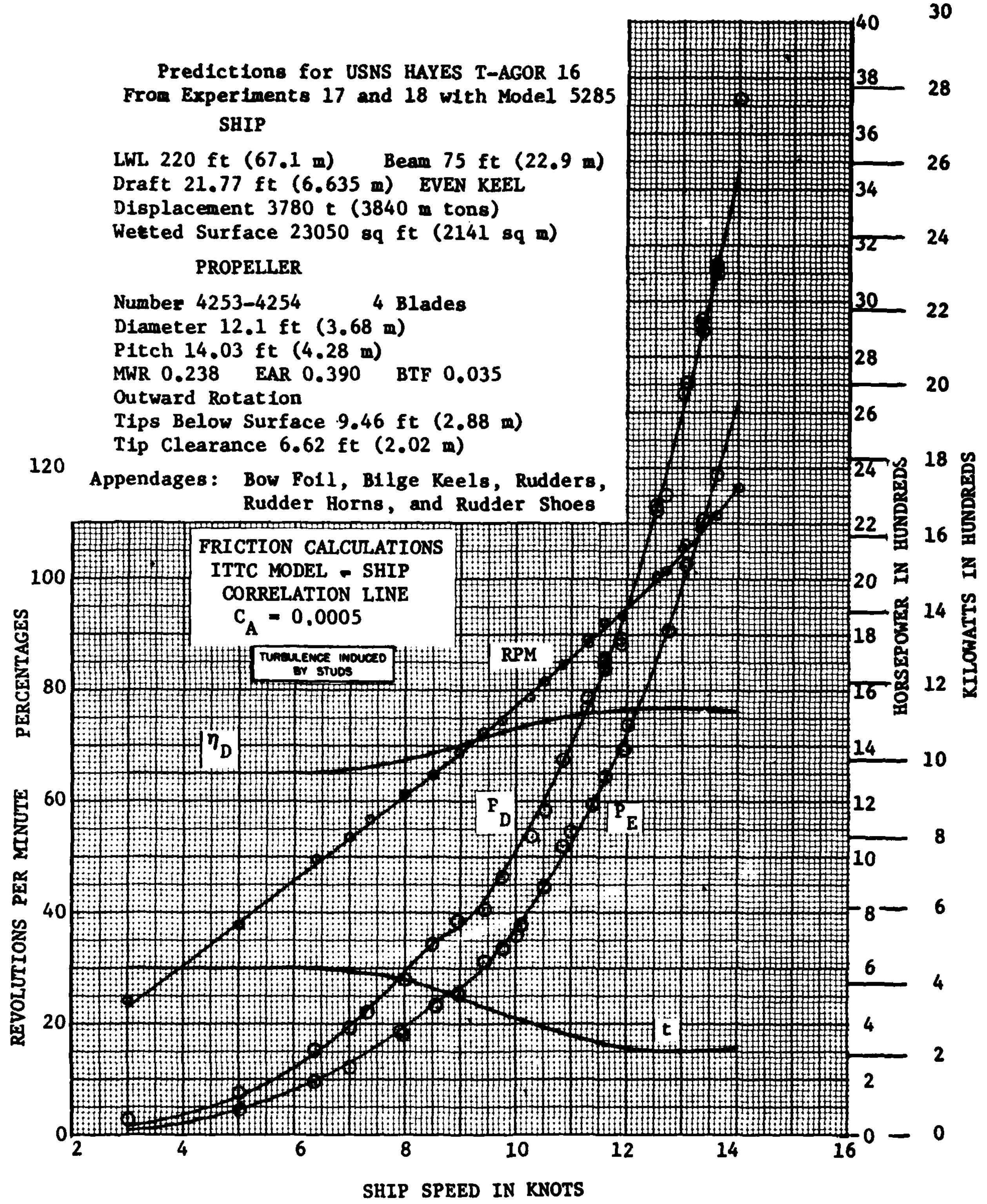


Figure 6 - Powering Predictions for USNS HAYES T-AGOR 16 with Bow Foil Represented by Model 5285 at Heavy Displacement Corresponding to 21.77 foot (6.635 meter) Draft Even Keel

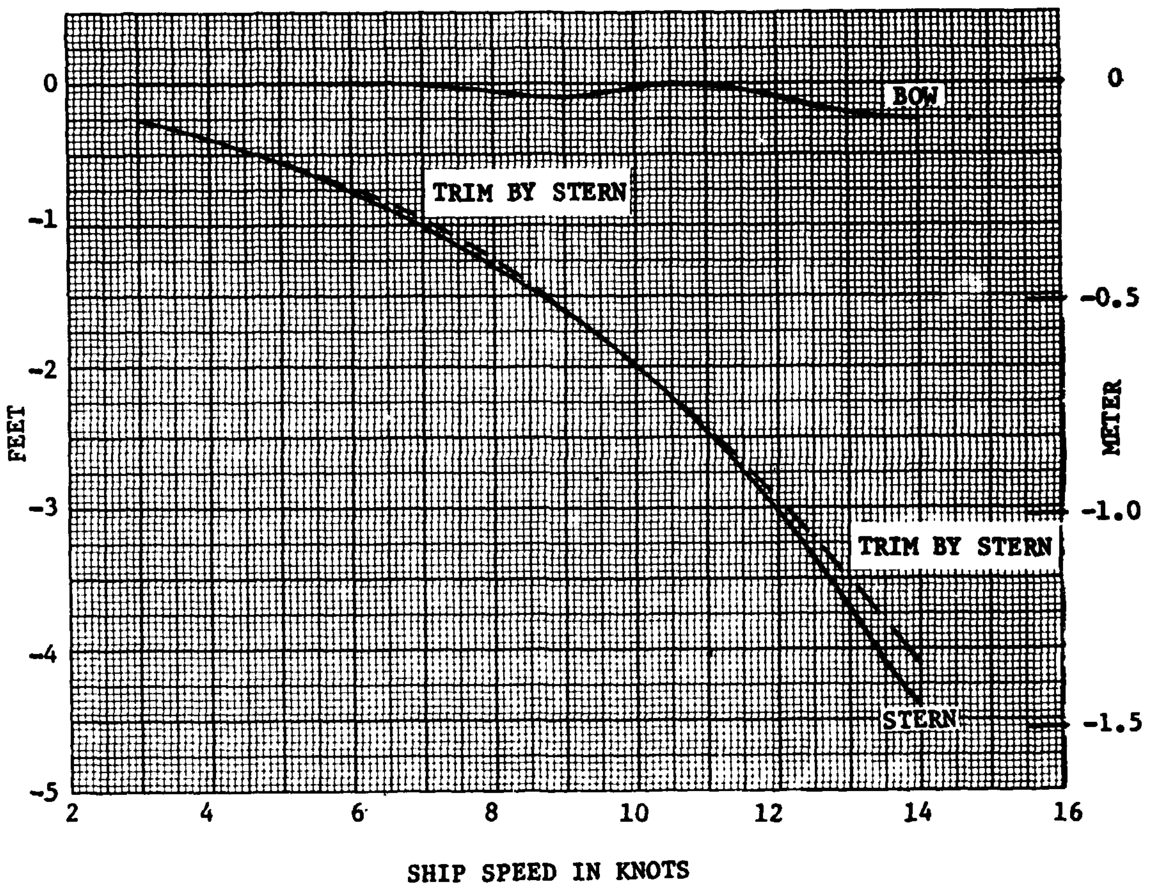


Figure 7 - Sinkage and Change of Level Curve from Resistance and Propulsion Experiments with Model 5285 Representing the USNS HAYES T-AGOR 16 with Bow Foil

SHIP	PROPELLER
LWL 220 ft (67.1 m) Beam 75 ft (22.9 m)	Number 4253-4254 4 Blades
Draft 21.77 ft (6.635 m) EVEN KEEL	Diameter 12.1 ft (4.28 m)
Displacement 3780 t (3840 m tons)	Pitch 14.03 ft (4.28 m)
Wetted Surface 23050 sq ft (2141 sq m)	MWR 0.238 EAR 0.390 BTF 0.035

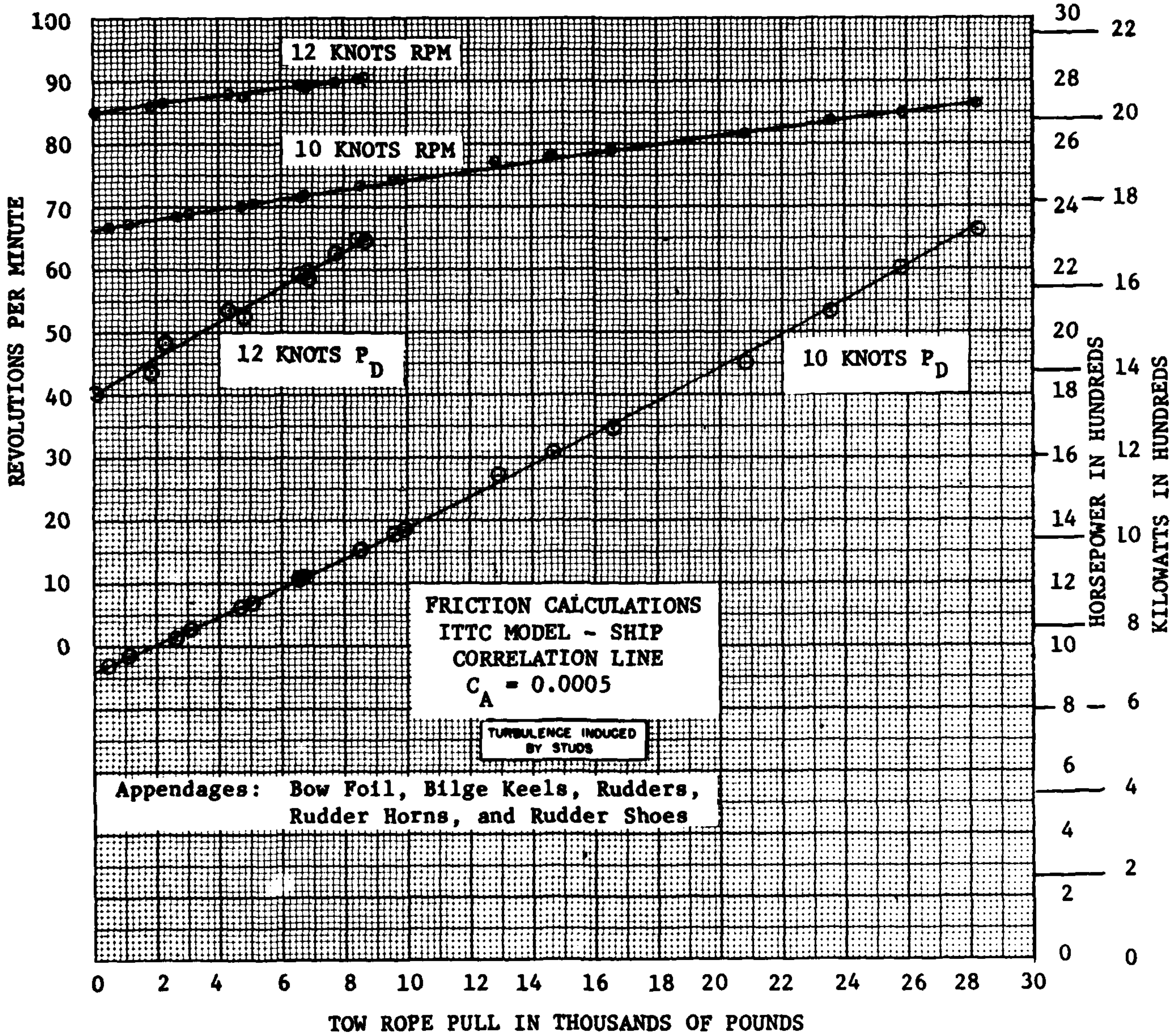


Figure 8 - Predictions of Power Requirements during Towing Operations of USNS HAYES T-AGOR 16 with Bow Foil Represented by Model 5285 at Heavy Displacement Corresponding to 21.77 foot (6.635 meter) Draft Even Keel Simulating Full-Scale Speeds of 10 and 12 Knots

Date	Displacement		True Wind Average		Air Temp		Water Temp		Water Specific Gravity	Sea State	Days From Last Hull Cleaning
	Ton	Metric Tons	Direction Deg.	Velocity Knots	°F	°C	°F	°C			
SECTOR RANGE											
5 Oct	3634	3692	190	18	75	23.9	74	23.3	1.024	2-3	14
6 Oct	3634	3692	210	18	72	22.2	75	23.9	1.024	2-3	15

Ship Characteristics	
Length Between Perpendiculars, feet (meters)	220.0 (67.06)
Length Overall, feet (meters)	246.4 (75.10)
Beam, Maximum, feet (meters)	75.0 (22.86)
Beam, Each Hull, feet (meters)	24.0 (7.32)
Distance Between Hulls, feet (meters)	27.0 (8.23)
Number of Rudders	2
Baseline Trial Displacement, tons (metric tons)	3634 (3692)
Towed Array Trial Displacement, tons (metric tons)	3600 (3658)
Baseline Trial Average Mean Draft, feet (meters)	21.3 (6.50)
Towed Array Trial Average Mean Draft, feet (meters)	21.0 (6.40)
Propeller Characteristics	
Number of Propellers	2
Number of Blades	4
Direction of Rotation	Outboard
Diameter, feet (meters)	12(3.66)
Design Pitch at the 0.7 Radius, degrees	27.3
Design Pitch at the 0.7 Radius, feet (meters)	13.64 (4.16)
Design Pitch Ratio, P/D	1.137
Propeller Manufacturer	LIPS, N.V. Drunen
Propeller Composition	Nickel-Aluminum Bronzes

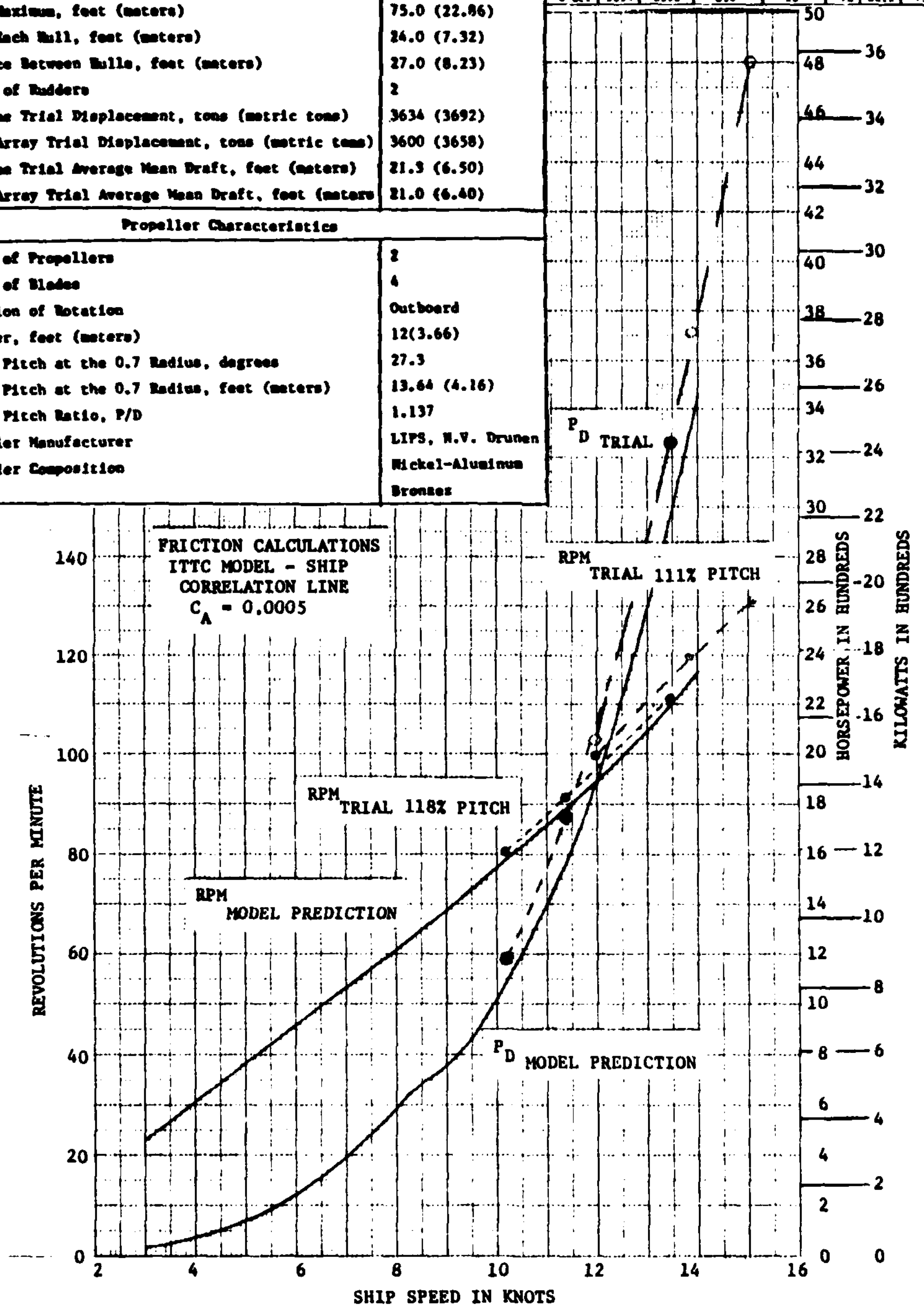
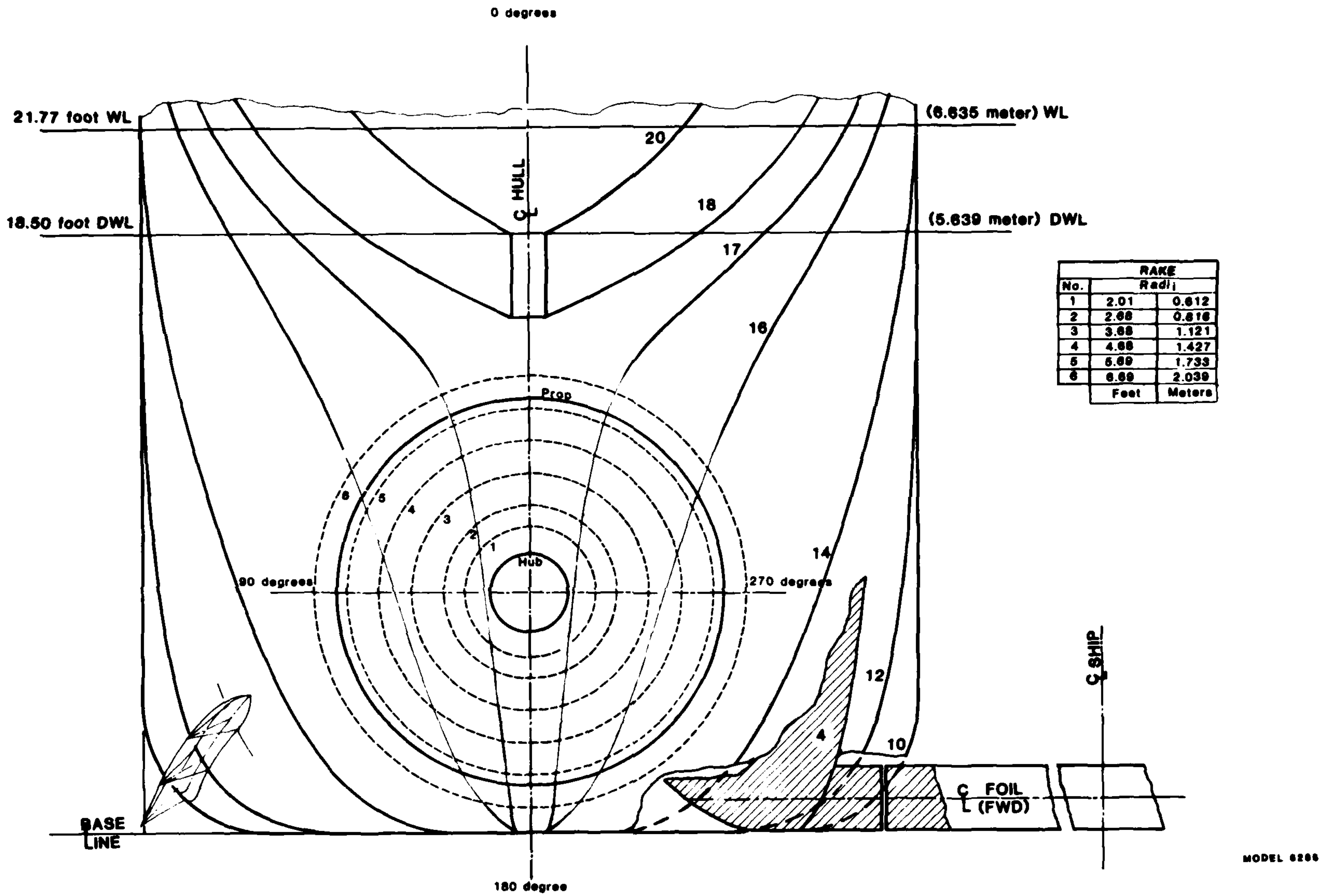


Figure 9 - Comparisons of Ship Standardization Trial Results and Model Powering Predictions for USNS HAYES T-AGOR 16 with Bow Foil



RAKE		
No.	Radii	
1	2.01	0.612
2	2.68	0.816
3	3.68	1.121
4	4.68	1.427
5	5.69	1.733
6	6.69	2.039
	Feet	Meters

Figure 10 - Port Hull Body Plan Showing Wake Survey Experimental Radii in Relation to Bilge Keels, Bow Foil, and Propeller Disk

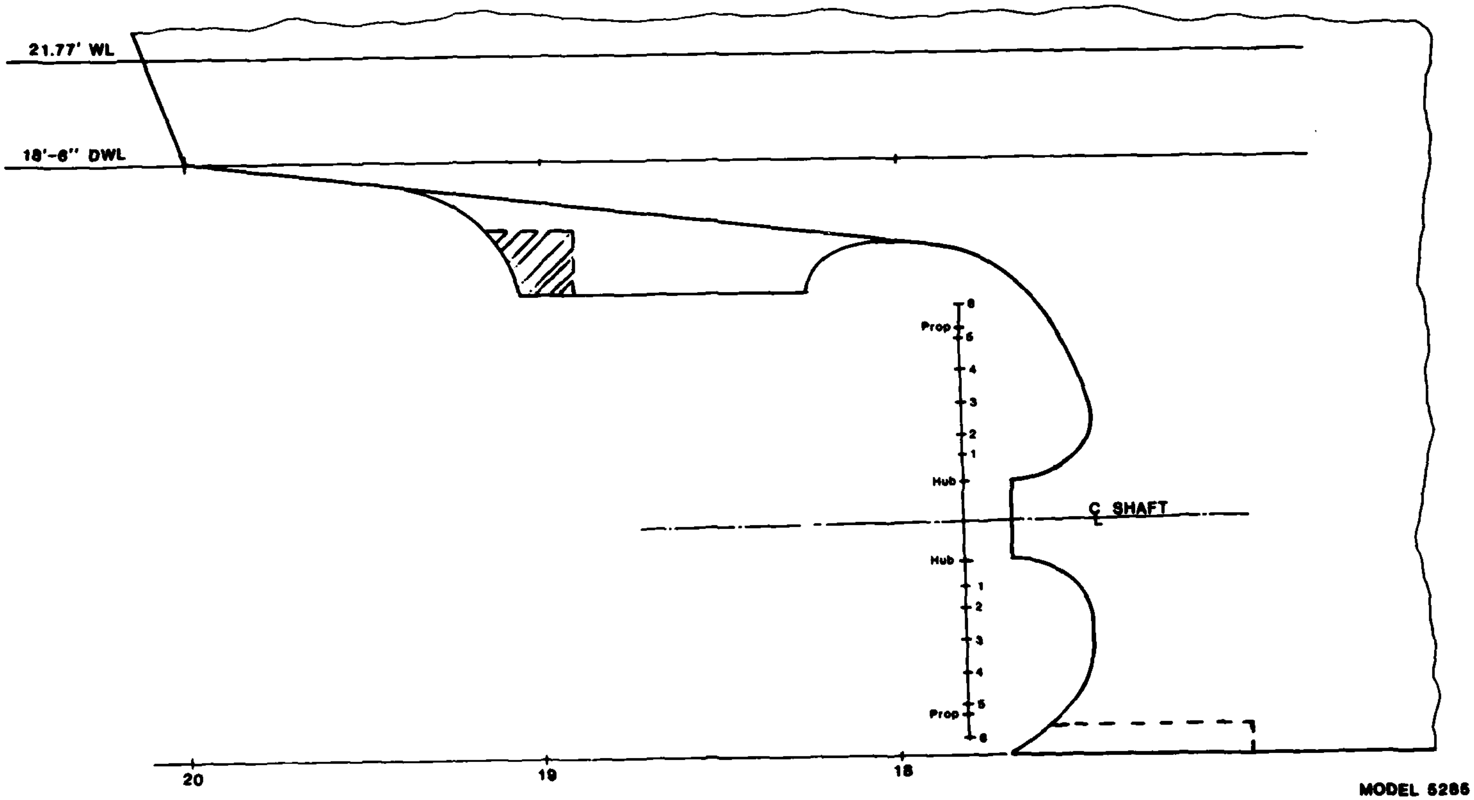
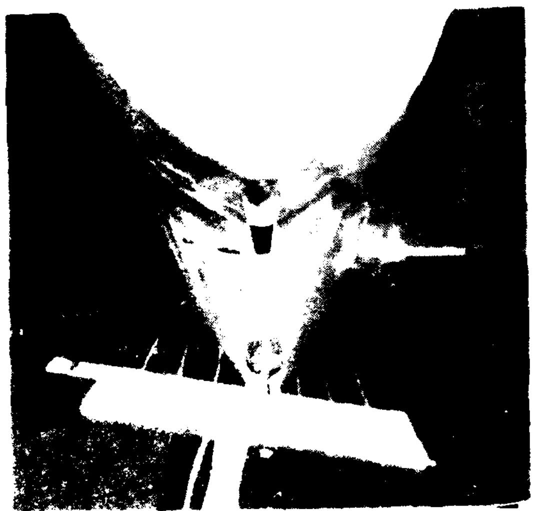


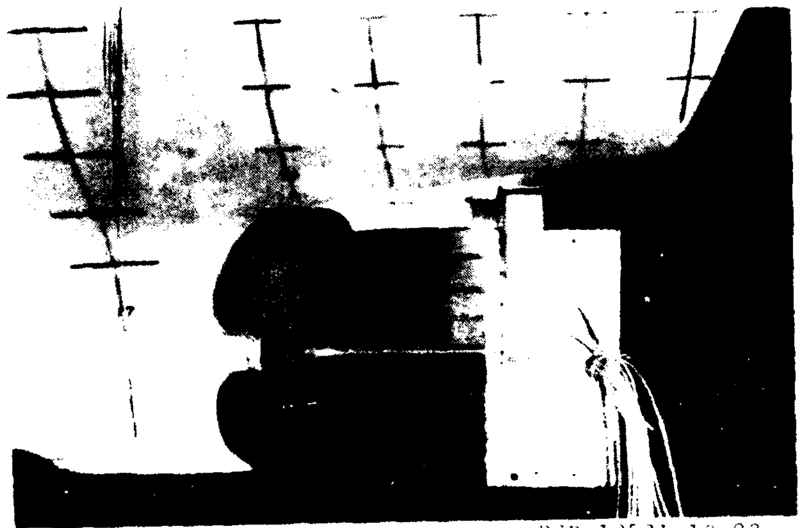
Figure 11 - Port Hull Stern Profile Showing Wake Survey Experimental Radii in Relation to Propeller Aperture and Stern Tube Ending

PSD 10518-10-83

PSD 10520-10-83



PSD 10519-10-83



PSD 10521-10-83

Figure 12 - Fitting Room Photographs Showing Wake Survey Rake Arrangement with Six Hemispherical Head Pitot Tubes in Port Hull of Model 5285

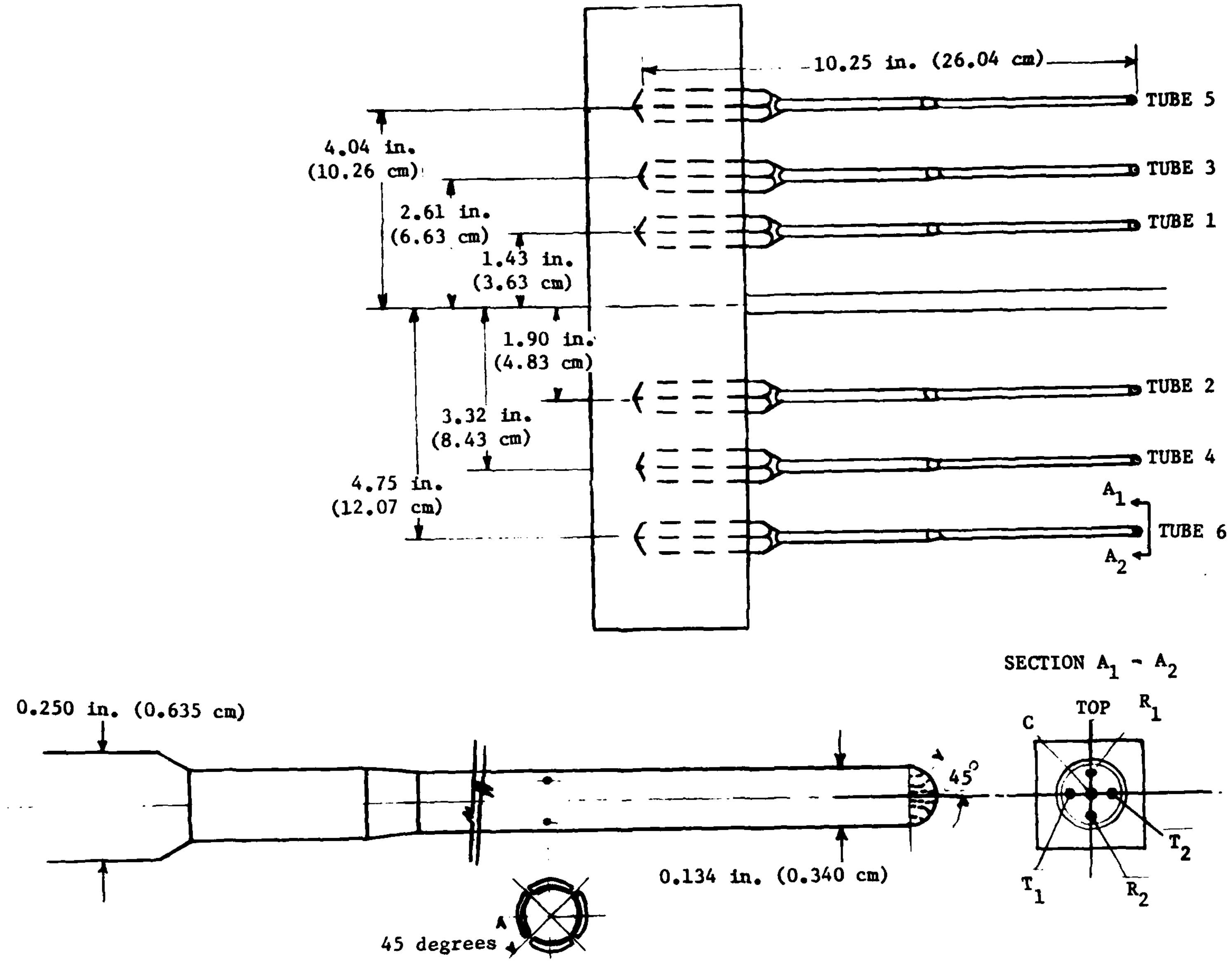


Figure 13 - Wake Survey Rake Arrangement Showing Six Hemispherical Head Pitot Tubes with Static Holes

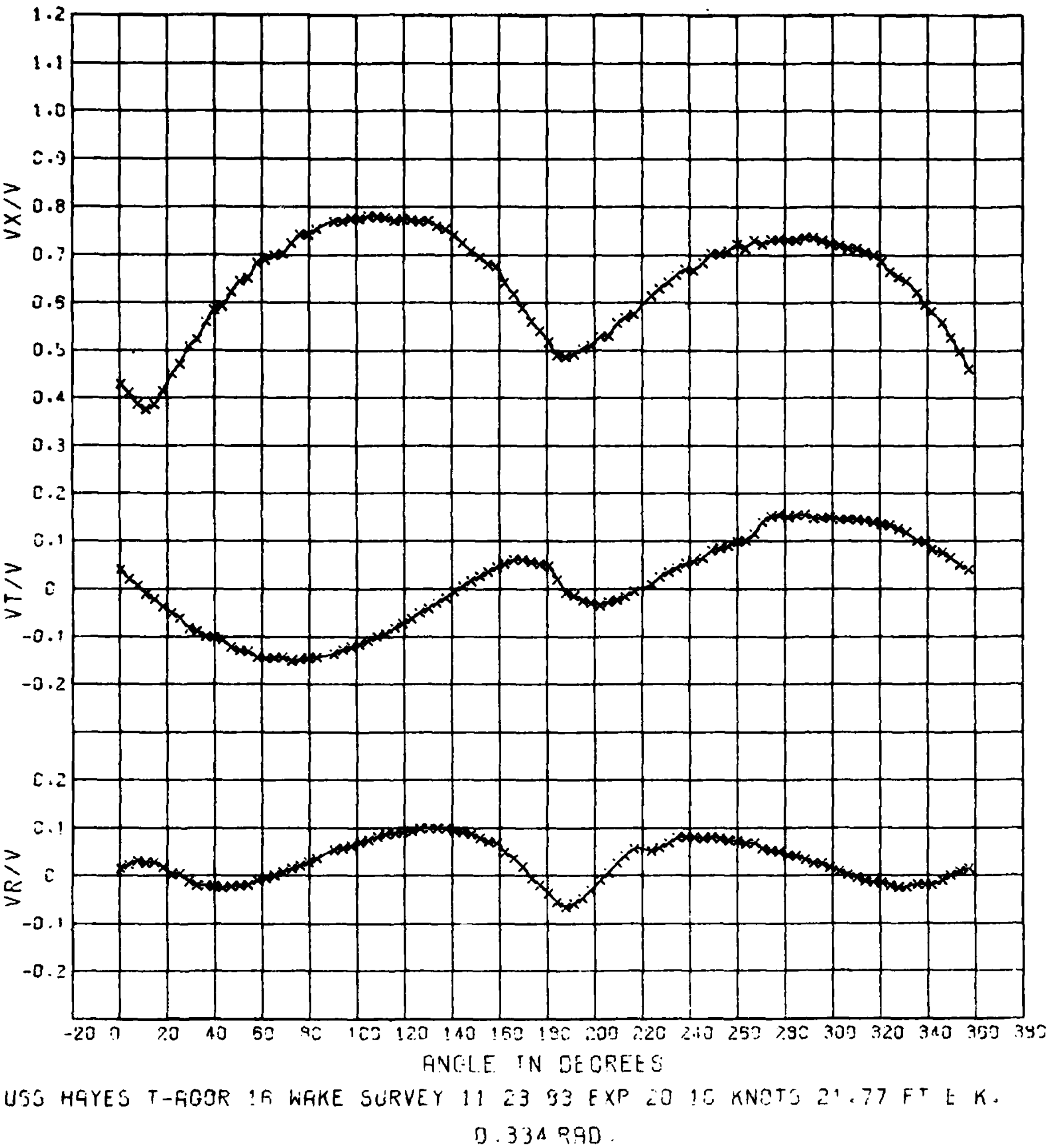


Figure 14 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 0.334

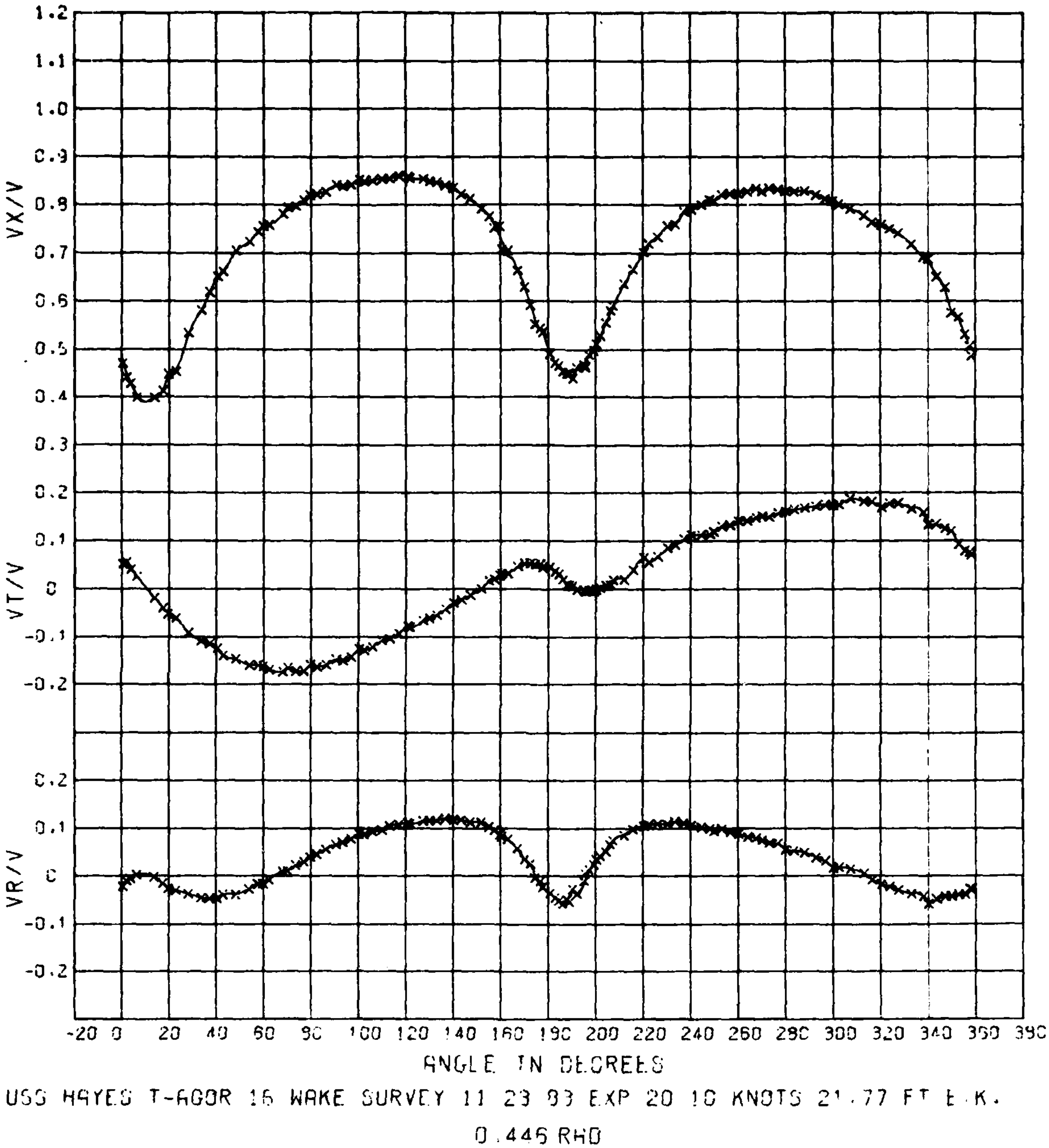


Figure 15 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 0.446

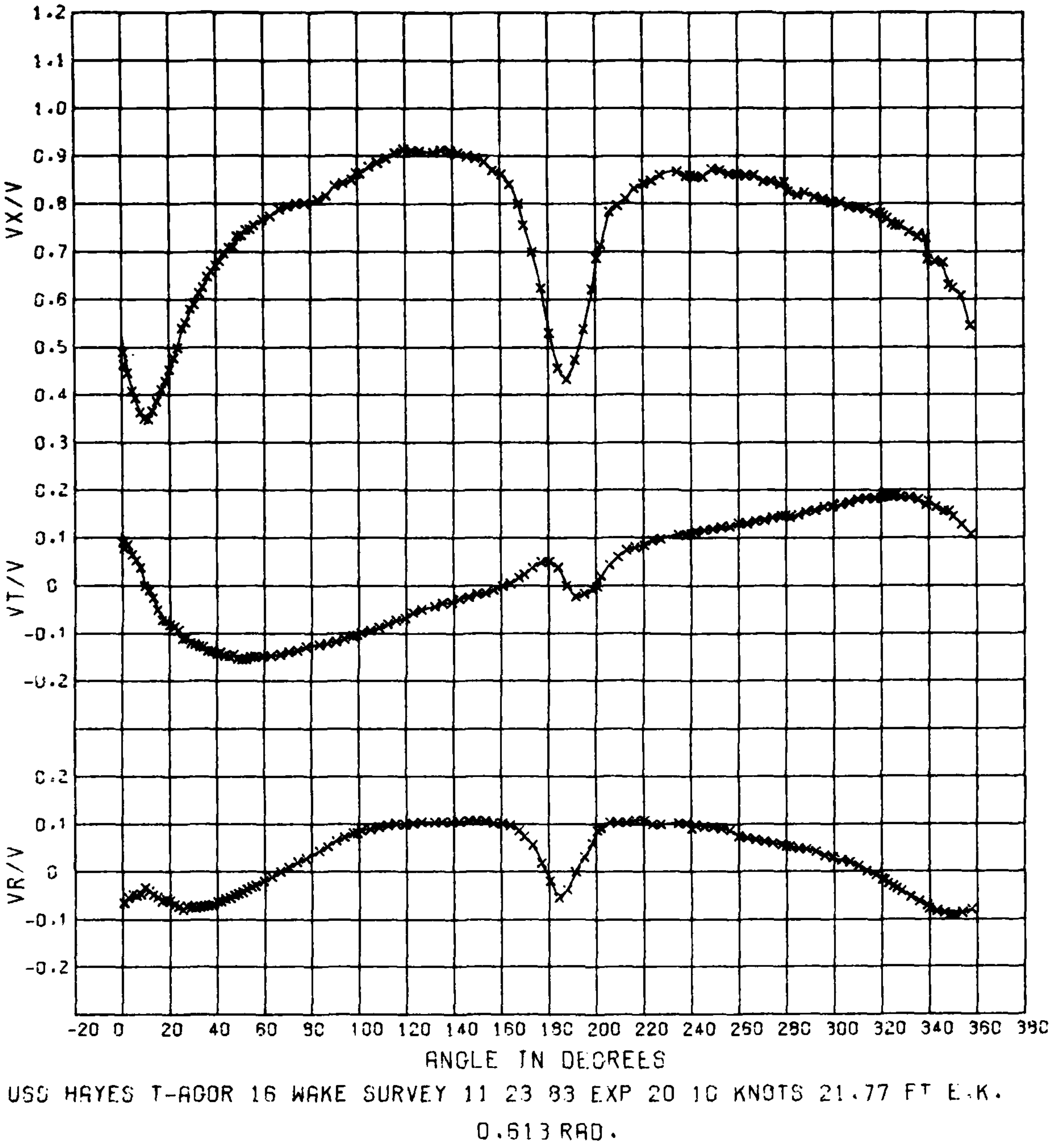


Figure 16 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 0.613

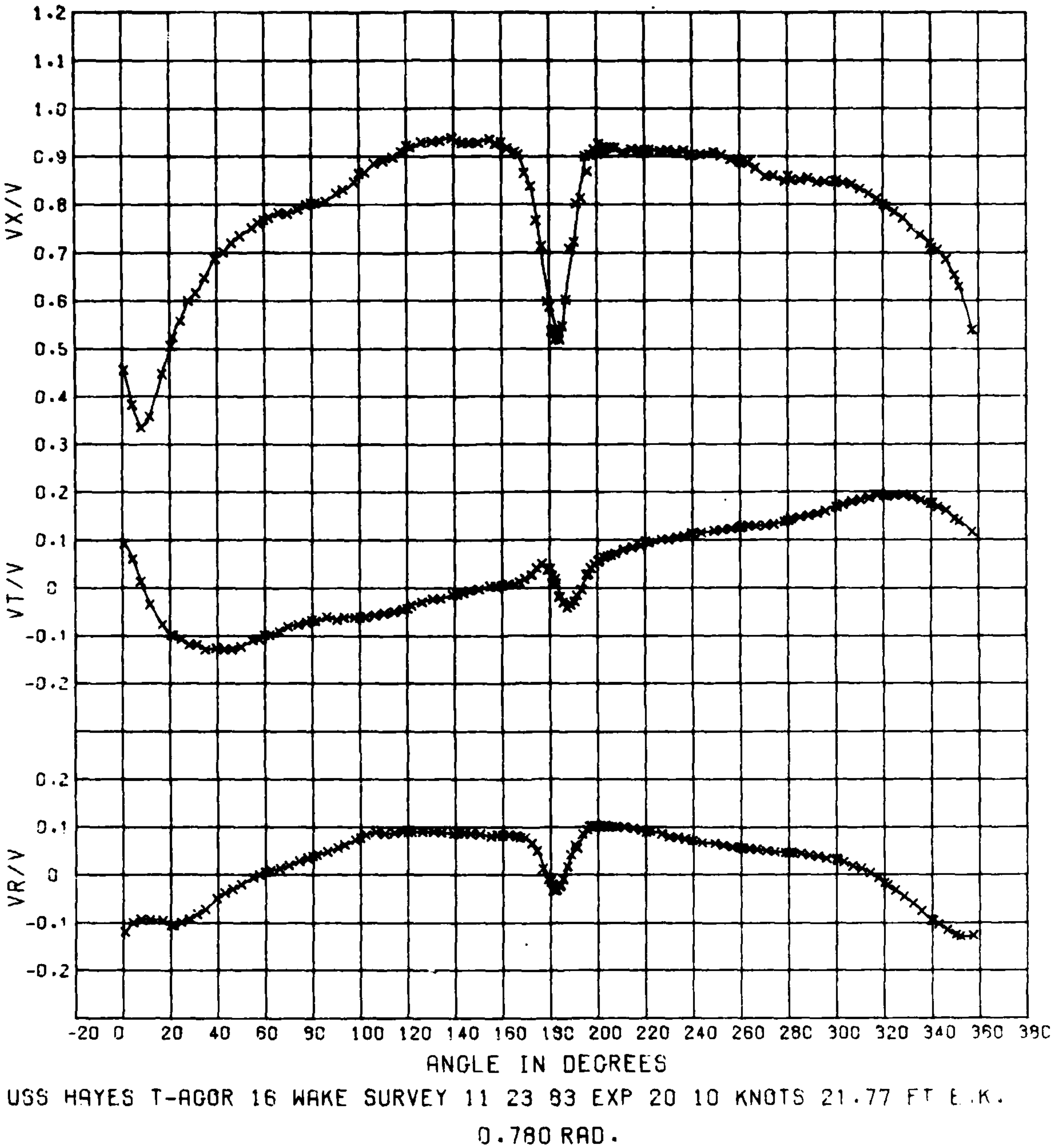


Figure 17 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 0.780

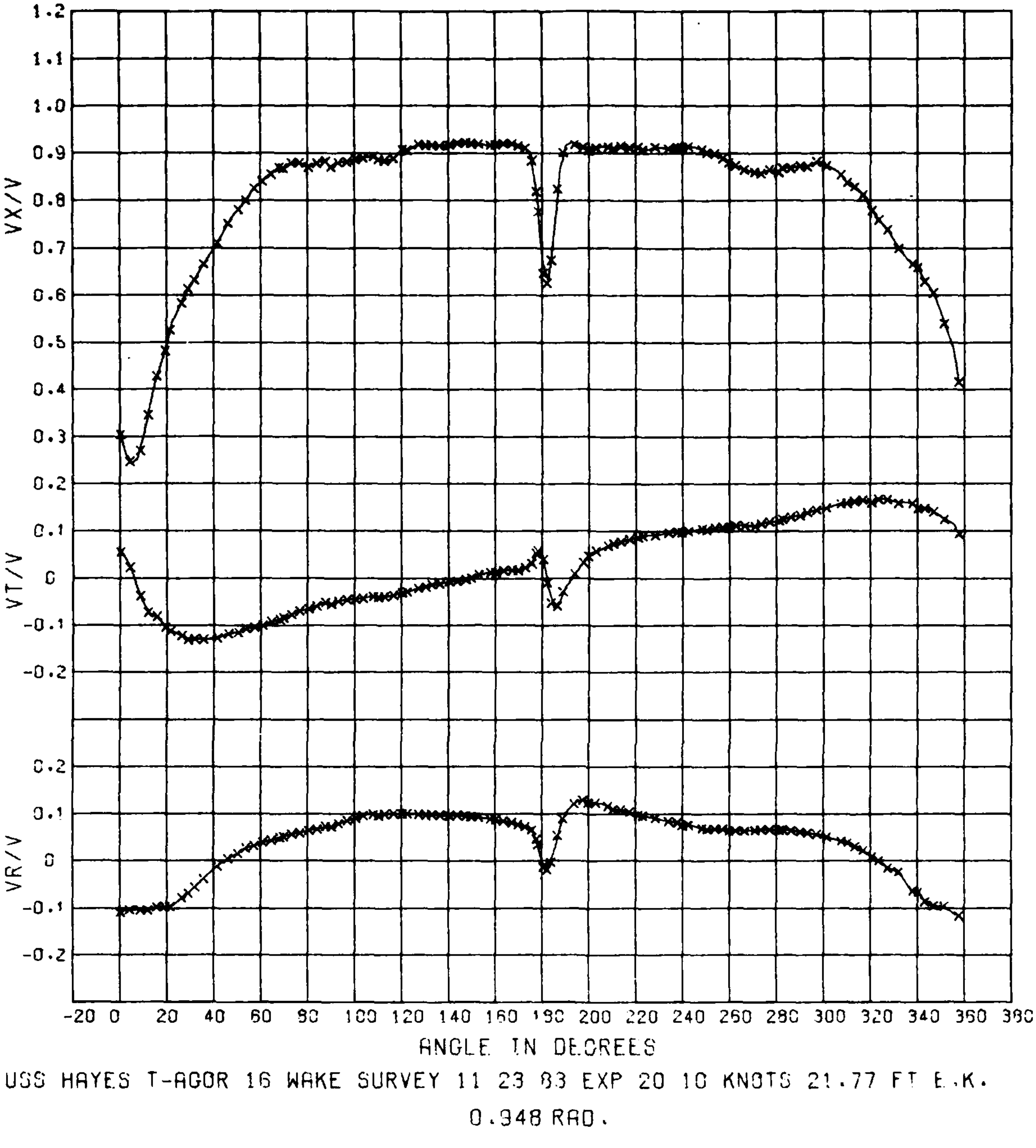


Figure 18 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 0.948

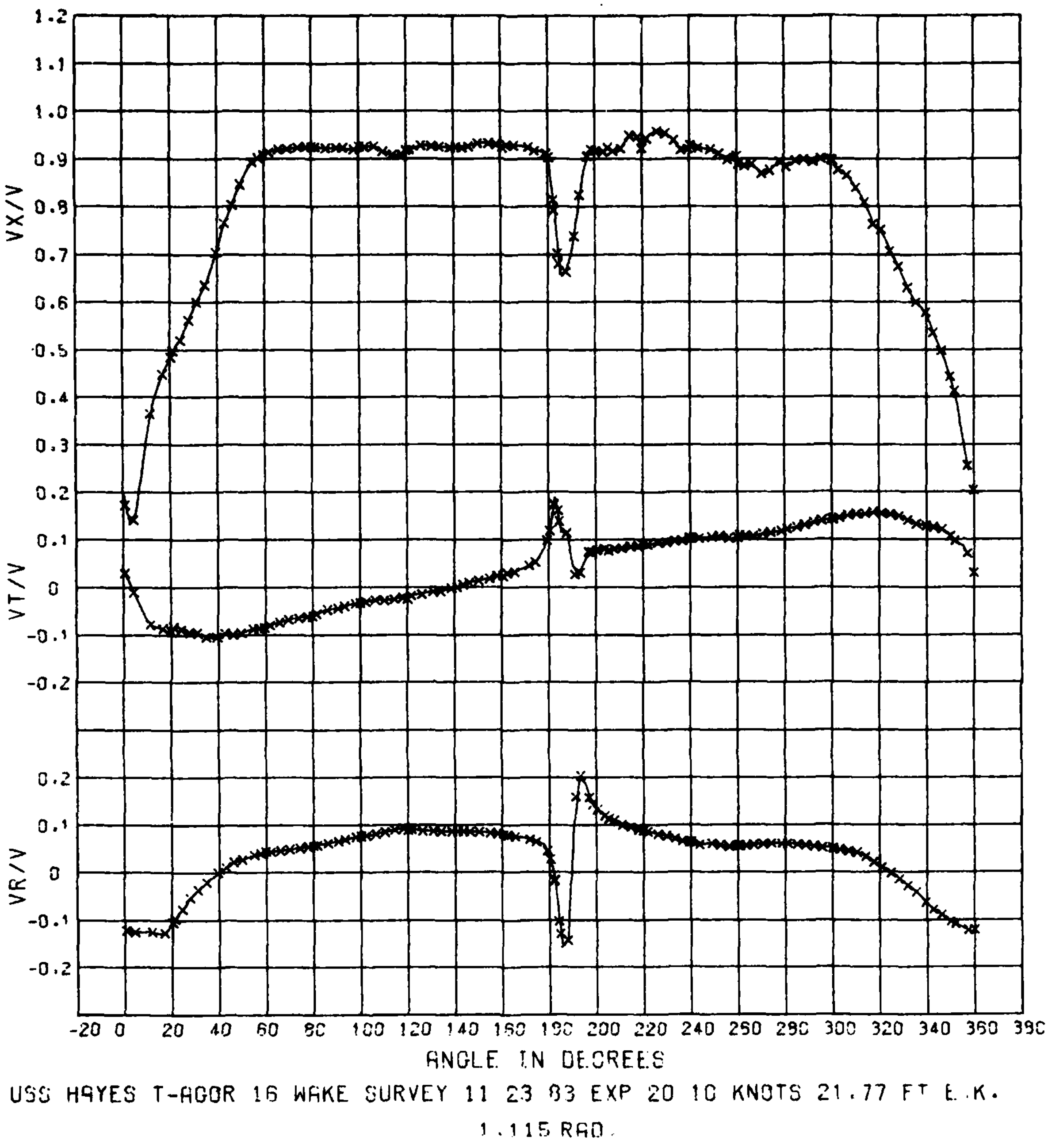


Figure 19 - Circumferential Distribution of Velocity Component Ratios for Model 5285 at a Radius Ratio of 1.115

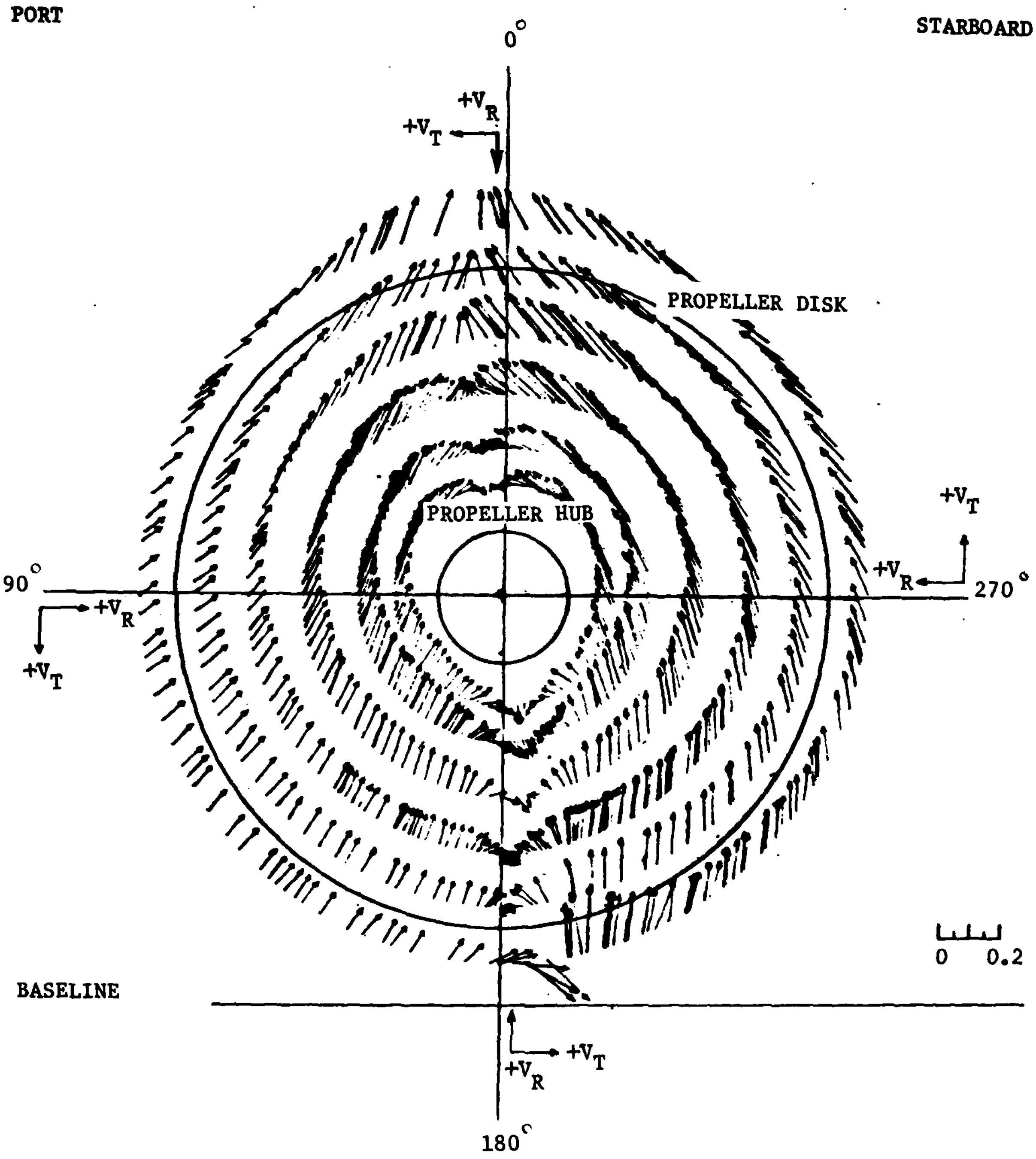


Figure 20 - Vector Diagram Showing Velocity Magnitude and Direction in the Propeller Plane from Experiment 20 with Model 5285

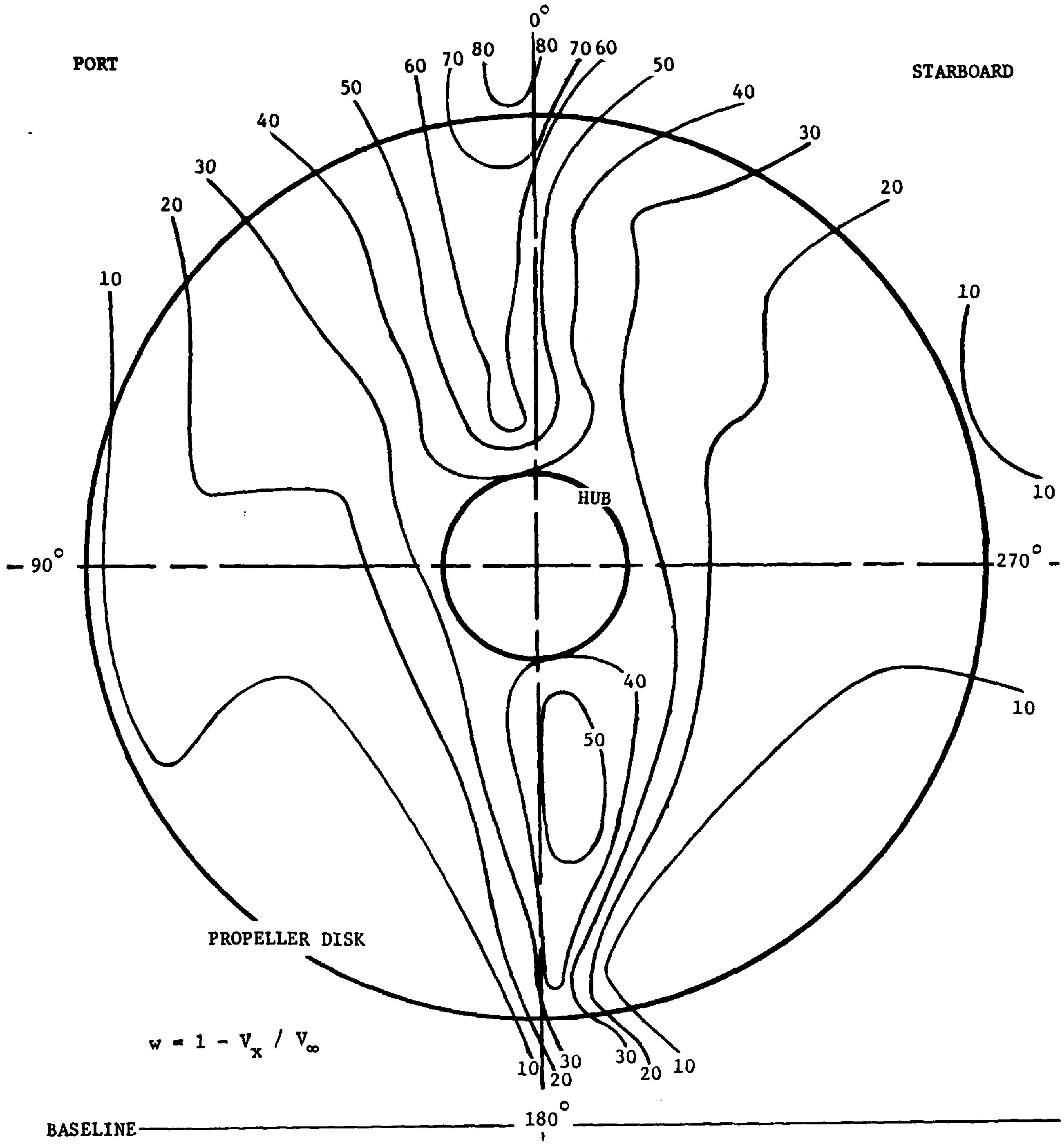


Figure 21 - Contour Plot Showing the Longitudinal Component Iso-Wake Distribution in the Propeller Plane from Experiment 20 with Model 5285

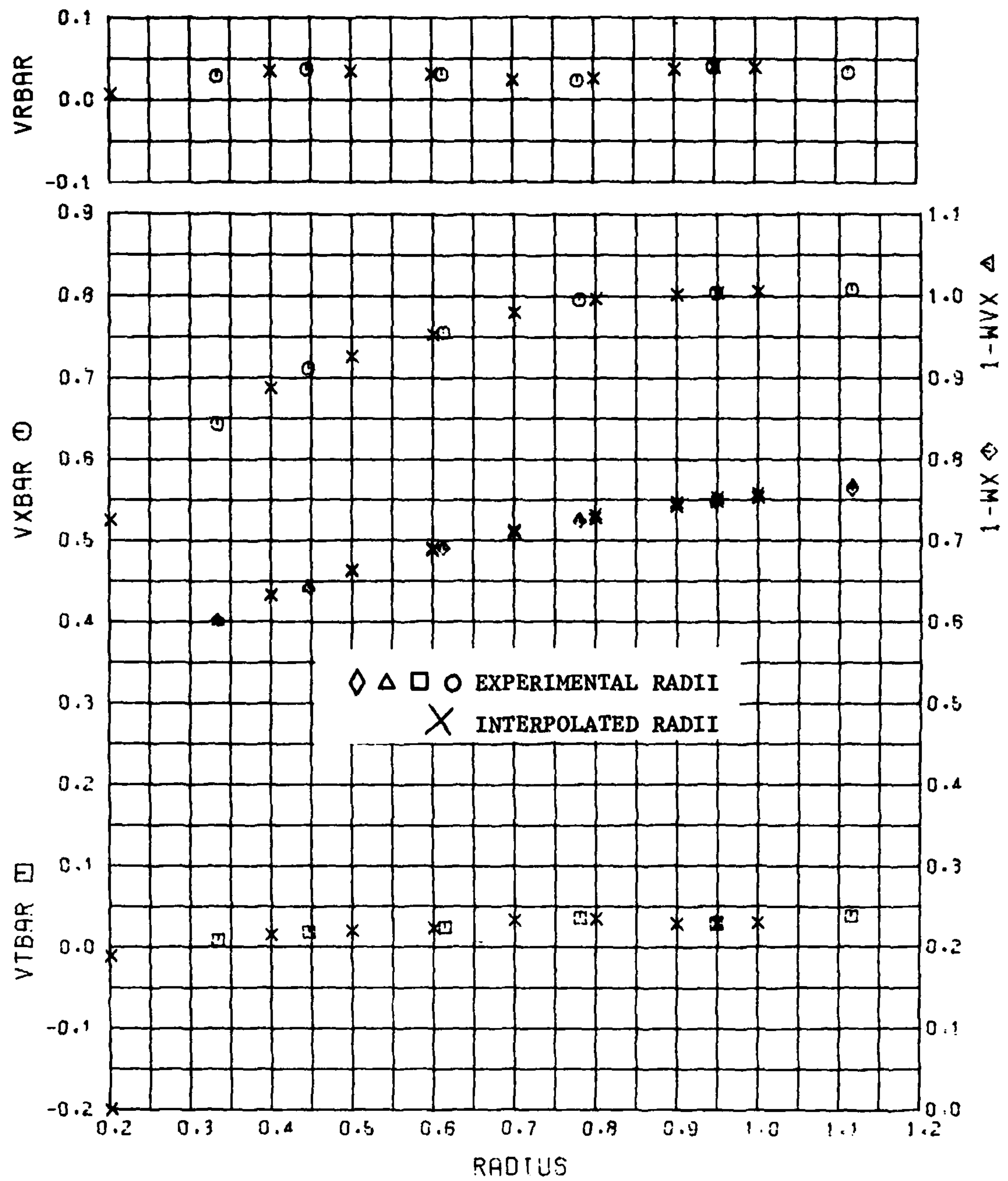


Figure 22 - Radial Distribution of the Mean Velocity Component Ratios from Experiment 20 with Model 5285

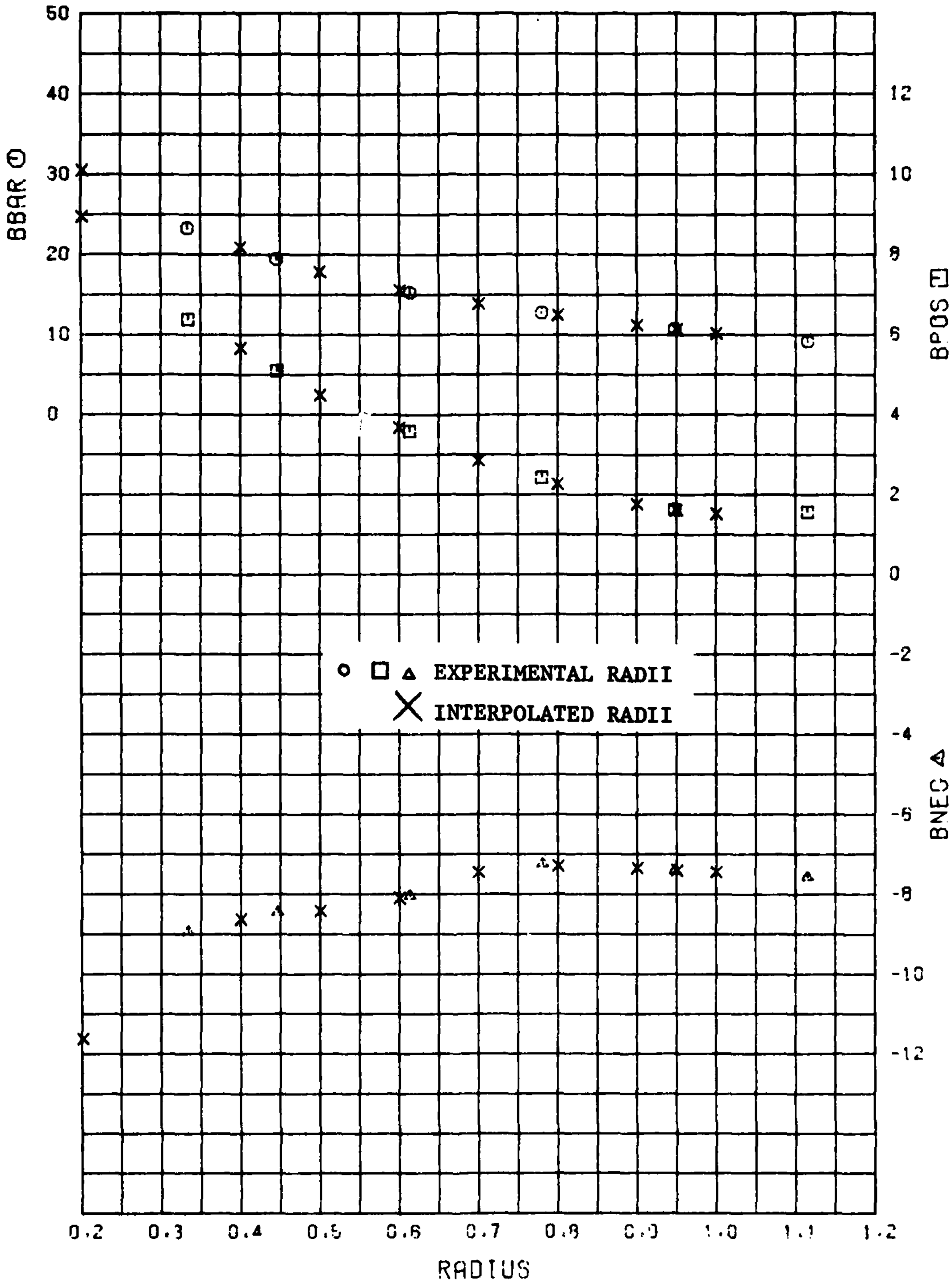


Figure 23 - Radial Distribution of the Mean Advance Angle and Advance Angle Variations from Experiment 20 with Model 5285

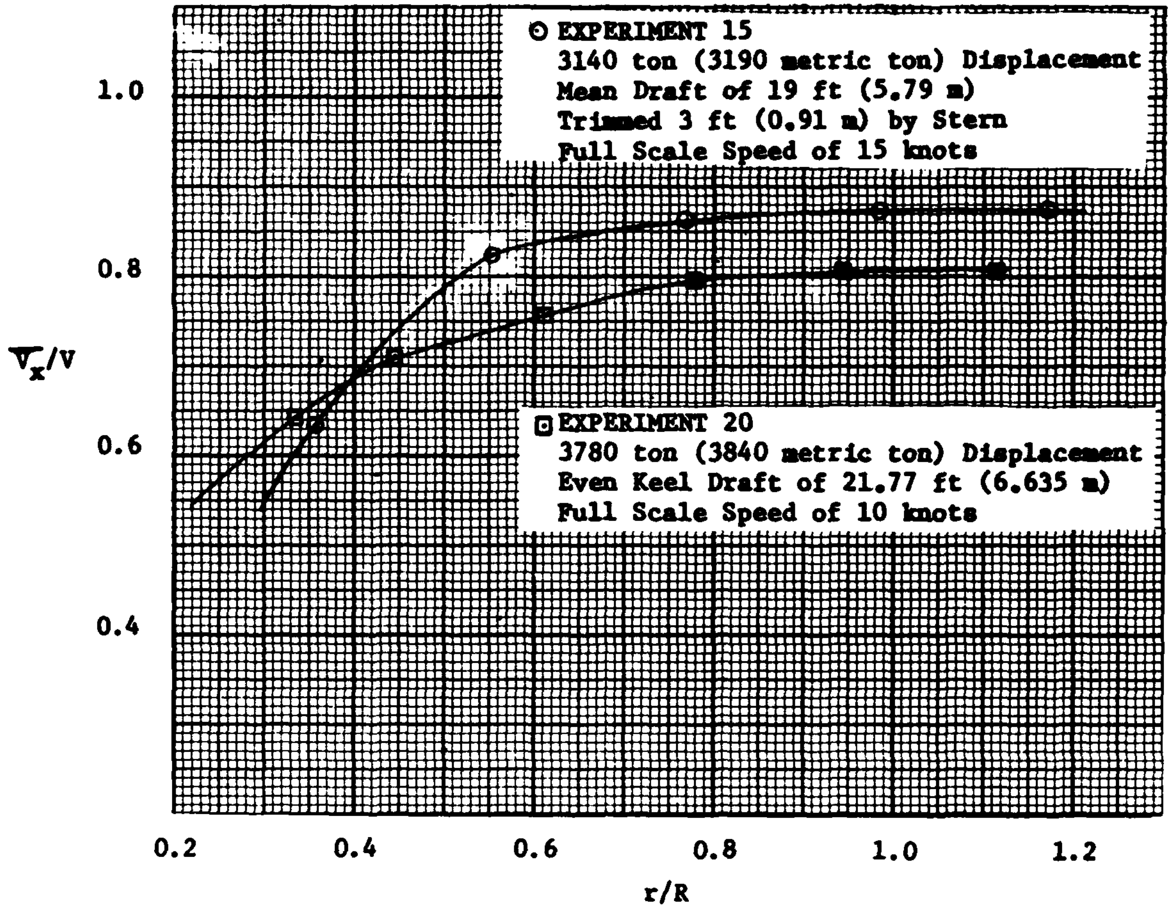


Figure 24 - Comparison of Mean Longitudinal Velocity Component Ratios from Experiments 15 and 20 with Model 5285 with Bow Foil

TABLE 1 - EXPERIMENTAL CONDITIONS DURING RESISTANCE, PROPULSION, TOWING AND WAKE SURVEY EXPERIMENTS WITH MODEL 5285 REPRESENTING USNS HAYES T-AGOR 16

Experiment Number	Experiment Type	Displacement	Draft	Trim By Stern	Wetted Surface	Speed Range	Remarks
		Tons (Metric Tons)	Feet (Meter)	Feet (Meter)	Square Feet (Square Meter)	Knots	
17	Resistance	3780 (3840)	21.77 (6.635)	0 (0)	23050 (2141)	3-13.5	with studs
18	Propulsion	3780 (3840)	21.77 (6.635)	0 (0)	23050 (2141)	3-14.0	with studs
19	Towing	3780 (3840)	21.77 (6.635)	0 (0)	23050 (2141)	10, 12	with studs
20	Wake Survey	3780 (3840)	21.77 (6.635)	0 (0)	23050 (2141)	10	with studs
21	Wake Survey	3780 (3840)	21.77 (6.635)	3.00 (0.914)	23050 (2141)	10	with studs
22	Wake Survey	3140 (3190)	19.00 (5.791)	3.00 (0.914)	20780 (1930)	15	with studs

TABLE 2 - POWERING PREDICTIONS FOR USNS HAYES T-AGOR 16 REPRESENTED BY MODEL 5285 AT HEAVY DISPLACEMENT CORRESPONDING TO 21.77 FOOT (6.635 METER) DRAFT EVEN KEEL

SHIP SPEED		EFFECTIVE POWER(PE)		DELIVERED POWER(PD)		PROPELLER REVOLUTIONS PER MINUTE
(KNOTS)	(M/SEC)	(HORSE-POWER)	(KILO-WATTS)	(HORSE-POWER)	(KILO-WATTS)	
3.0	1.54	20.	15.	25.	20.	22.8
4.0	2.06	45.	35.	70.	50.	30.4
5.0	2.57	90.	70.	140.	105.	38.0
6.0	3.09	160.	120.	250.	185.	45.7
6.5	3.34	210.	155.	320.	235.	49.5
7.0	3.60	260.	195.	395.	295.	53.3
7.5	3.86	320.	240.	485.	360.	57.1
8.0	4.12	395.	295.	585.	435.	61.0
8.5	4.37	470.	350.	690.	515.	64.9
9.0	4.63	525.	390.	750.	560.	68.9
9.5	4.89	620.	460.	865.	645.	73.0
10.0	5.14	745.	555.	1020.	760.	77.1
10.5	5.40	895.	665.	1200.	900.	81.4
11.0	5.66	1070.	790.	1410.	1050.	85.6
11.5	5.92	1250.	930.	1640.	1230.	90.1
12.0	6.17	1450.	1080.	1900.	1410.	94.7
12.5	6.43	1710.	1270.	2220.	1650.	99.6
13.0	6.69	1990.	1480.	2580.	1920.	104.9
13.5	6.94	2310.	1720.	3010.	2240.	110.4
14.0	7.20	2640.	1970.	3470.	2590.	116.5

SHIP SPEED	EFFICIENCIES(ETA)				THRUST DEDUCTION AND WAKE FACTORS			ADVANCE COEF.
(KNOTS)	ETAD	ETAO	ETAH	ETAR	1-THDF	1-WFTT	1-WFTQ	ADVC
3.0	.650	.690	.940	1.005	.700	.745	.750	.820
4.0	.650	.670	.980	.990	.700	.715	.710	.785
5.0	.650	.655	1.015	.980	.700	.690	.675	.760
6.0	.650	.640	1.045	.975	.700	.670	.650	.740
6.5	.655	.635	1.055	.975	.700	.665	.645	.735
7.0	.655	.635	1.060	.975	.705	.665	.645	.735
7.5	.665	.640	1.065	.980	.710	.670	.650	.735
8.0	.675	.645	1.065	.985	.720	.680	.665	.745
8.5	.685	.655	1.060	.990	.735	.695	.685	.760
9.0	.700	.690	1.005	1.015	.750	.750	.760	.820
9.5	.720	.695	1.005	1.025	.770	.765	.780	.835
10.0	.735	.695	1.025	1.025	.790	.770	.785	.835
10.5	.745	.695	1.050	1.020	.805	.770	.785	.830
11.0	.755	.690	1.065	1.020	.820	.770	.780	.825
11.5	.760	.695	1.075	1.020	.830	.775	.790	.825
12.0	.765	.695	1.075	1.025	.840	.785	.800	.830
12.5	.770	.690	1.080	1.030	.845	.785	.805	.820
13.0	.770	.690	1.075	1.040	.850	.790	.815	.820
13.5	.765	.685	1.070	1.050	.850	.795	.830	.810
14.0	.760	.685	1.045	1.065	.845	.805	.855	.810

TABLE 3 - TOWING PREDICTIONS FOR USNS HAYES T-AGOR 16 REPRESENTED BY MODEL 5285 AT HEAVY DISPLACEMENT CORRESPONDING TO 21.77 FOOT (6.635 METER) DRAFT EVEN KEEL

TOW ROPE PULL		10 KNOTS			12 KNOTS		
		POWER		RPM	POWER		RPM
		hp	(kW)		hp	kw	
POUNDS (NEWTON) IN THOUSANDS							
0.0	0	920	(686)	66.2	1805	(1346)	85.0
4.0	(17.79)	1096	(817)	69.6	2030	(1514)	87.7
8.0	(35.59)	1278	(953)	72.8	2255	(1682)	90.0
12.0	(53.38)	1475	(1100)	75.6			
16.0	(71.17)	1676	(1250)	78.4			
20.0	(88.96)	1884	(1405)	81.4			
24.0	(106.76)	2100	(1566)	83.9			
28.0	(124.55)	2325	(1734)	86.3			
MAXIMUM 28.3	(125.88)	2340	(1745)	86.5	2300	(1715)	90.2

TABLE 4 - USNS HAYES T-AGOR 16 TRIAL DATA AT TWO PITCH CONDITIONS

ENGLISH UNITS

Run No.	Mini-Ranger Speed (knot)	EM Log Speed (knot)	Shaft RPM STBD	Shaft RPM PORT	Shaft RPM AVG	Shaft Torque (lbf-ft) STBD	Shaft Torque PORT	Shaft Torque TOTAL	Shaft Power (hp) STBD	Shaft Power PORT	Shaft Power TOTAL	Propeller Pitch (percent) STBD	Propeller Pitch PORT	Propeller Pitch AVG
S1700N	11.43	13.3	100.0	99.4	99.7	51,600	53,400	105,000	980	1,010	1,990	109.7	113.6	111.6
S1710S	12.56	12.8	100.0	99.2	99.6	54,200	56,600	110,800	1,030	1,070	2,100	109.6	113.6	111.6
S1720N	11.39	13.3	100.0	99.3	99.6	51,700	53,400	105,100	980	1,010	1,990	109.6	113.6	111.6
AVG	11.98	13.0			99.6			107,900			2,050			111.6
S1730S	14.51	15.0	119.9	119.4	119.6	80,300	84,900	165,200	1,830	1,930	3,760	109.4	113.4	111.4
S1740N	13.28	15.3	120.1	119.3	119.7	77,400	81,700	159,100	1,770	1,860	3,630	109.4	113.4	111.4
S1750S	14.32	15.0	120.1	119.6	119.8	80,900	85,900	166,800	1,850	1,960	3,810	109.4	113.4	111.4
AVG	13.85	15.2			119.7			162,600			3,710			111.4
S1760S	15.89	16.2	131.4	131.3	131.4	95,600	102,300	197,900	2,390	2,560	4,950	109.3	113.3	111.3
S1770N	14.34	16.9	131.4	131.0	131.2	91,300	95,900	187,200	2,280	2,390	4,670	109.4	113.3	111.4
S1780S	15.75	16.2	131.4	130.5	131.0	96,300	101,600	197,900	2,410	2,520	4,930	109.3	113.3	111.3
AVG	15.08	16.6			131.2			192,500			4,800			111.4
S1300N	10.18	11.4	80.7	80.1	80.4	38,200	36,100	74,300	590	550	1,140	117.6	119.2	118.4
S1310S	10.24	10.7	80.8	80.1	80.4	40,700	39,000	79,700	630	590	1,220	117.6	119.1	118.4
S1320N	10.10	11.3	80.8	79.9	80.4	38,500	36,100	74,600	590	550	1,140	117.6	119.1	118.4
AVG	10.19	11.0			80.4			77,100			1,180			118.4
S1330N	11.32	12.8	91.1	91.3	91.2	49,100	48,000	97,100	850	830	1,680	117.5	118.9	118.2
S1340S	11.45	12.0	91.2	91.2	91.2	52,700	51,800	104,500	920	900	1,820	117.5	118.9	118.2
AVG	11.38	12.4			91.2			100,800			1,750			118.2
S1360N	13.30	15.0	110.9	111.3	111.1	75,300	75,000	150,300	1,590	1,590	3,180	117.3	118.7	118.0
S1370S	13.61	14.5	110.9	111.1	111.0	79,000	78,900	157,900	1,670	1,670	3,340	117.3	118.7	118.0
AVG	13.46	14.8			111.0			154,100			3,260			118.0

TABLE 4 - CONTINUED

METRIC UNITS

Run No.	Mini-Ranger Speed (knot)	EM Log Speed (knot)	Shaft RPM STBD	Shaft RPM PORT	Shaft RPM AVG	Shaft Torque (N-m) STBD	Shaft Torque (N-m) PORT	Shaft Torque (N-m) TOTAL	Shaft Power (kW) STBD	Shaft Power (kW) PORT	Shaft Power (kW) TOTAL	Propeller Pitch (percent) STBD	Propeller Pitch (percent) PORT	Propeller Pitch (percent) AVG
S1700N	11.43	13.3	100.0	99.4	99.7	69,900	72,400	142,300	730	750	1,480	109.7	113.6	111.6
S1710S	12.56	12.8	100.0	99.2	99.6	73,400	76,800	150,200	770	800	1,570	109.6	113.6	111.6
S1720N	11.39	13.3	100.0	99.3	99.6	70,100	72,400	142,500	730	750	1,480	109.6	113.6	111.6
AVG	11.98	13.0			99.6			146,300			1,530			111.6
S1730S	14.51	15.0	119.9	119.4	119.6	108,900	115,100	224,000	1,370	1,440	2,810	109.4	113.4	111.4
S1740N	13.28	15.3	120.1	119.3	119.7	104,900	110,800	215,700	1,320	1,380	2,700	109.4	113.4	111.4
S1750S	14.32	15.0	120.1	119.6	119.8	109,700	116,500	226,200	1,380	1,460	2,840	109.4	113.4	111.4
AVG	13.85	15.2			119.7			220,400			2,760			111.4
S1760S	15.89	16.2	131.4	131.3	131.4	129,600	138,700	268,300	1,780	1,910	3,690	109.3	113.3	111.3
S1770N	14.34	16.9	131.4	131.0	131.2	123,700	130,000	253,700	1,700	1,780	3,480	109.4	113.3	111.4
S1780S	15.75	16.2	131.4	130.5	131.0	130,500	137,800	268,300	1,800	1,880	3,680	109.3	113.3	111.3
AVG	15.08	16.6			131.2			261,000			3,580			111.4
S1300N	10.18	11.4	80.7	80.1	80.4	51,900	49,000	100,900	440	410	850	117.6	119.2	118.4
S1310S	10.24	10.7	80.8	80.1	80.4	55,200	52,900	108,100	470	440	910	117.6	119.1	118.4
S1320N	10.10	11.3	80.8	79.9	80.4	52,100	48,900	101,000	440	410	850	117.6	119.1	118.4
AVG	10.19	11.0			80.4			104,500			880			118.4
S1330N	11.32	12.8	91.1	91.3	91.2	66,600	65,100	131,700	630	620	1,250	117.5	118.9	118.2
S1340S	11.45	12.0	91.2	91.2	91.2	71,500	70,300	141,800	680	670	1,350	117.5	118.9	118.2
AVG	11.38	12.4			91.2			136,700			1,300			118.2
S1360N	13.30	15.0	110.9	111.3	111.1	102,100	101,700	203,800	1,190	1,190	2,380	117.3	118.7	118.0
S1370S	13.61	14.5	110.9	111.1	111.0	107,100	107,000	214,100	1,240	1,240	2,480	117.3	118.7	118.0
AVG	13.46	14.8			111.0			209,000			2,430			118.0

TABLE 5 - COMPARISON OF SHIP STANDARDIZATION TRIAL RESULTS AND MODEL POWERING PREDICTIONS FOR USNS HAYES T-AGOR 16 WITH BOW FOIL

MODEL					
SPEED IN KNOTS		11	12	13	14
P_D	hp (kW)	1410 (1050)	1900 (1410)	2580 (1920)	3470 (2590)
RPM		85.6	94.7	104.9	116.5
C_A = 0.0005					
SHIP					
PITCH - 118%					
P_D	hp (kW)	1550 (1160)	2120 (1580)	2875 (2140)	
RPM		87.9	97.2	106.7	
PITCH - 111%					
P_D	hp (kW)		2075 (1550)	3785 (2820)	4760 (3550)
RPM			99.8	110.4	120.7

TABLE 6 - EXPERIMENTAL WAKE SURVEY DATA FROM MODEL 5285 WITH BOW FOIL REPRESENTING USNS HAYES T-AGOR 16 AT 10 KNOTS

WAKE ANALYSIS
PROGRAM VERSION OF [illegible]

USS HAYES T-AGOR 16 WAKE SURVEY [illegible] 10 KNOTS [illegible]
PROPELLER DIAMETER = 12.00 FEET

INPUT DATA

RADIUS = [illegible]

ANGLE	VX/V	VT/V	VR/V
[illegible]	.429	[illegible]	.01[illegible]
3.[illegible]	.411	.321	.023
7.[illegible]	.387	[illegible]	.033
10.9	.377	-.310	.027
14.[illegible]	.347	-.321	.025
18.2	.416	-.23[illegible]	.018
21.[illegible]	.451	-.[illegible]	.003
25.3	.472	-.[illegible]	.005
29.1	.5[illegible]	-.[illegible]43	-.011
32.[illegible]	.52[illegible]	-.[illegible]	-.015
36.3	.555	-.100	-.020
[illegible]	.5[illegible]	-.102	-.027
[illegible]	.5[illegible]	-.137	-.024
47.0	.[illegible]	-.12[illegible]	-.022
[illegible].7	.644	-.120	-.020
[illegible].2	.651	-.131	-.019
[illegible].0	.6[illegible]	-.1[illegible]	-.009
[illegible]	.6[illegible]	-.1[illegible]	-.004
[illegible].2	.700	-.1[illegible]	.011
[illegible]	.713	-.145	.008

TABLE 6 - CONTINUED

RADIUS = .790

ANGLE	VR/V	VT/V	VZ/V
.4	.440	.099	-.110
.9	.443	.091	-.120
4.2	.370	.055	-.095
4.2	.380	.064	-.104
7.6	.336	.314	-.097
11.4	.339	-.035	-.093
16.7	.440	-.076	-.094
20.4	.512	-.090	-.104
20.4	.501	-.097	-.107
21.5	.525	-.098	-.105
24.9	.550	-.107	-.090
27.8	.601	-.119	-.091
31.2	.616	-.119	-.081
34.8	.640	-.124	-.071
38.9	.676	-.123	-.053
39.9	.703	-.124	-.045
42.9	.701	-.126	-.037
46.2	.720	-.120	-.030
49.8	.735	-.123	-.020
54.3	.747	-.111	-.008
55.5	.756	-.106	-.004
57.5	.762	-.107	-.001
59.7	.763	-.100	.005
60.0	.772	-.096	.008
61.9	.777	-.099	.010
66.0	.782	-.091	.014
69.8	.781	-.040	.020
74.1	.790	-.074	.029
77.7	.790	-.077	.036
79.3	.807	-.306	.041
80.6	.794	-.066	.038
[illegible]	[illegible]	[illegible]	[illegible]

RADIUS = .948

ANGLE	VR/V	VT/V	VZ/V
.3	.305	.055	-.110
4.2	.267	.023	-.165
8.1	.268	-.019	-.107
9.9	.277	-.034	-.204
11.9	.366	-.073	-.106
15.8	.428	-.082	-.098
19.4	.481	-.105	-.098
21.6	.527	-.117	-.097
26.4	.584	-.122	-.079
29.1	.514	-.131	-.069
31.9	.533	-.124	-.056
35.7	.667	-.131	-.038
40.9	.697	-.127	-.013
42.3	.723	-.127	-.009
46.2	.752	-.119	.005
[illegible]	[illegible]	[illegible]	[illegible]

RADIUS = 1.119

ANGLE	VR/V	VT/V	VZ/V
.4	.191	.029	-.124
.9	.195	.030	-.121
4.2	.143	-.010	-.123
4.2	.141	-.013	-.179
11.4	.365	-.079	-.175
16.7	.449	-.096	-.129
20.4	.477	-.095	-.110
20.4	.497	-.040	-.101
23.3	.498	-.093	-.097
24.5	.520	-.C08	-.077
27.8	.567	-.094	-.052
31.2	.600	-.076	-.036
34.4	.636	-.165	-.320
38.0	.730	-.344	-.301
40.6	.680	-.110	.301
[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7 - TABULATED VALUES OF THE MEAN VELOCITY COMPONENT RATIOS, THE VOLUMETRIC MEAN WAKE VELOCITY, THE MEAN ADVANCE ANGLES AND OTHER DERIVED QUANTITIES AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE USNS HAYES T-AGOR 16 WITH BOW FOIL AT 10 KNOTS REPRESENTED BY MODEL 5285

WAKE ANALYSIS
PROGRAM VERSION OF 11/01/79

USS HAYES T-AGOR 16 WAKE SURVEY 11 23 83 EXP 20 10 KNOTS 21.77 FT E.K.
PROPELLER DIAMETER = 12.00 FEET JV = .703

RADIUS =	.334	.446	.613	.780	.948	1.115	.202	.400	.500	.600	.700	.800	.900	.950	1.000
VXBAR =	.643	.711	.756	.796	.804	.807	.525	.687	.726	.753	.780	.797	.802	.804	.806
VTBAR =	.009	.019	.024	.036	.029	.038	-.011	.015	.020	.023	.033	.035	.029	.029	.030
VRBAR =	.029	.037	.031	.023	.040	.034	.007	.035	.035	.031	.024	.026	.037	.040	.040
1-WVX =	.599	.642	.693	.727	.752	.768	0.000	.633	.664	.690	.712	.732	.747	.753	.758
1-WX =	.602	.642	.690	.723	.747	.762	0.000	.634	.663	.688	.709	.727	.742	.748	.753
BBAR =	23.21	19.46	15.30	12.73	10.68	9.13	30.50	20.86	17.85	15.55	13.87	12.45	11.20	10.66	10.15
BPOS =	6.37	5.10	3.58	2.42	1.62	1.56	8.94	5.66	4.48	3.67	2.85	2.26	1.76	1.62	1.52
THETA =	90.00	100.00	120.00	137.50	127.50	227.50	200.00	90.00	117.50	120.00	137.50	137.50	127.50	127.50	127.50
BNEG =	-8.94	-8.45	-8.04	-7.24	-7.40	-7.57	-11.62	-8.63	-8.42	-8.10	-7.45	-7.29	-7.34	-7.40	-7.44
THETA =	10.00	10.00	10.00	7.50	5.00	2.50	0.00	10.00	10.00	10.00	10.00	7.50	7.50	5.00	5.00

VXBAR IS CIRCUMFERENTIAL MEAN LONGITUDINAL VELOCITY.
VTBAR IS CIRCUMFERENTIAL MEAN TANGENTIAL VELOCITY.
VRBAR IS CIRCUMFERENTIAL MEAN RADIAL VELOCITY.
1-WVX IS VOLUMETRIC MEAN WAKE VELOCITY WITHOUT TANGENTIAL CORRECTION.
1-WX IS VOLUMETRIC MEAN WAKE VELOCITY WITH TANGENTIAL CORRECTION.
BBAR IS MEAN ANGLE OF ADVANCE.
BPOS IS VARIATION BETWEEN THE MAXIMUM AND MEAN ADVANCE ANGLES (DELTA BETA PLUS).
BNEG IS VARIATION BETWEEN THE MINIMUM AND MEAN ADVANCE ANGLES (DELTA BETA MINUS).
THETA IS ANGLE IN DEGREES AT WHICH CORRESPONDING BPOS OR BNEG OCCURS.

TABLE 8 - HARMONIC ANALYSIS OF THE LONGITUDINAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE USNS HAYES T-AGOR 16 WITH BOW FOIL AT 10 KNOTS REPRESENTED BY MODEL 5285

WAKE ANALYSIS
PROGRAM VERSION OF 11/01/79

USS HAYES T-AGOR 16 WAKE SURVEY 11 23 83 EXP 20 10 KNOTS 21.77 FT E.K.
PROPELLER DIAMETER = 12.00 FEET JV = .703

HARMONIC ANALYSES OF LONGITUDINAL VELOCITY COMPONENT RATIOS (VX/V)

HARMONIC =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RADIUS = .334																
AMPLITUDE =	.037	.142	.010	.040	.006	.014	.004	.006	.002	.004	.003	.002	.001	.001	.000	.001
PHASE ANGLE =	295.0	242.8	235.6	229.4	206.5	219.3	174.6	196.1	136.6	200.9	128.7	199.5	107.2	75.7	324.3	111.8
RADIUS = .446																
AMPLITUDE =	.033	.176	.008	.068	.007	.030	.004	.012	.002	.003	.001	.002	.001	.001	.001	.001
PHASE ANGLE =	274.6	245.2	99.2	226.5	125.5	211.2	139.9	195.5	102.6	173.8	113.1	155.9	111.5	156.2	86.2	132.1
RADIUS = .613																
AMPLITUDE =	.083	.148	.018	.086	.015	.049	.016	.030	.009	.018	.007	.012	.004	.008	.001	.004
PHASE ANGLE =	265.1	245.7	167.8	234.2	111.3	216.4	67.2	203.1	65.4	186.5	51.2	167.8	29.8	149.1	95.8	104.0
RADIUS = .780																
AMPLITUDE =	.133	.110	.021	.073	.018	.041	.020	.035	.015	.025	.014	.019	.011	.013	.008	.020
PHASE ANGLE =	256.7	245.7	203.0	246.9	159.8	234.3	116.0	229.8	103.9	225.0	89.7	221.8	76.5	207.1	61.5	201.8
RADIUS = .948																
AMPLITUDE =	.159	.120	.063	.063	.015	.026	.014	.029	.009	.023	.008	.017	.007	.014	.007	.012
PHASE ANGLE =	264.9	257.4	246.7	246.7	220.1	238.1	185.6	234.9	177.0	228.3	140.8	232.1	121.4	225.3	88.0	230.1
RADIUS = 1.115																
AMPLITUDE =	.184	.157	.081	.075	.010	.028	.006	.026	.016	.023	.010	.019	.009	.015	.011	.012
PHASE ANGLE =	270.8	266.3	259.8	250.7	288.1	223.6	311.2	233.2	302.1	229.2	292.6	216.3	298.9	187.9	299.3	183.8

WAKE ANALYSIS
PROGRAM VERSION OF 11/01/79

USS HAYES T-AGOR 16 WAKE SURVEY 11 23 83 EXP 20 10 KNOTS 21.77 FT E.K.
PROPELLER DIAMETER = 12.00 FEET JV = .703

HARMONIC ANALYSES OF LONGITUDINAL VELOCITY COMPONENT RATIOS (VX/V)

HARMONIC =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RADIUS = .202																
AMPLITUDE =	.074	.051	.042	.017	.017	.011	.005	.008	.005	.017	.008	.011	.003	.006	.002	.005
PHASE ANGLE =	298.9	224.7	243.9	351.0	241.9	337.8	103.1	216.7	100.2	205.7	99.2	195.9	51.7	93.5	286.4	99.3
RADIUS = .400																
AMPLITUDE =	.031	.167	.003	.058	.005	.024	.004	.009	.002	.003	.001	.001	.001	.001	.000	.001
PHASE ANGLE =	283.8	244.5	137.5	226.4	148.5	211.9	165.6	194.0	129.4	161.1	142.7	173.2	128.6	117.6	74.3	132.7
RADIUS = .500																
AMPLITUDE =	.050	.168	.015	.077	.011	.040	.008	.020	.005	.010	.003	.006	.001	.004	.000	.003
PHASE ANGLE =	271.2	245.4	96.1	229.1	108.6	212.2	70.5	195.5	60.9	173.7	37.9	150.6	9.9	134.2	176.3	86.6
RADIUS = .600																
AMPLITUDE =	.079	.151	.019	.086	.015	.049	.016	.029	.009	.017	.006	.011	.004	.008	.001	.005
PHASE ANGLE =	265.8	245.7	105.3	233.5	109.7	215.7	65.8	201.9	63.6	184.5	48.6	164.9	25.8	146.2	111.4	99.6
RADIUS = .700																
AMPLITUDE =	.112	.122	.016	.079	.018	.045	.020	.034	.014	.022	.013	.016	.009	.010	.006	.007
PHASE ANGLE =	257.4	244.3	151.2	242.0	141.2	227.1	98.1	221.0	91.3	214.1	79.0	207.8	65.6	190.6	59.2	181.6
RADIUS = .800																
AMPLITUDE =	.136	.109	.026	.071	.017	.038	.018	.035	.014	.025	.014	.019	.011	.013	.009	.010
PHASE ANGLE =	257.8	247.0	214.7	246.7	168.0	235.3	125.6	230.6	112.7	225.4	96.6	224.2	84.6	212.6	69.5	210.2
RADIUS = .900																
AMPLITUDE =	.152	.114	.053	.064	.015	.029	.015	.031	.011	.023	.011	.017	.009	.014	.009	.012
PHASE ANGLE =	262.9	254.1	241.6	246.2	205.6	238.6	170.5	233.9	155.0	227.5	126.8	231.8	112.4	226.1	87.4	230.0
RADIUS = .950																
AMPLITUDE =	.160	.120	.063	.063	.015	.026	.014	.029	.009	.023	.008	.017	.007	.014	.007	.012
PHASE ANGLE =	265.0	257.5	246.9	246.7	220.7	238.1	186.1	234.9	178.0	228.3	141.5	232.1	121.8	225.2	87.9	230.0
RADIUS = 1.000																
AMPLITUDE =	.167	.129	.072	.065	.014	.025	.012	.028	.007	.022	.005	.017	.004	.014	.004	.012
PHASE ANGLE =	267.0	260.7	251.0	247.6	235.2	235.5	200.3	235.2	213.2	228.9	165.8	229.8	134.3	219.4	76.7	224.4

TABLE 9 - HARMONIC ANALYSIS OF THE TANGENTIAL VELOCITY COMPONENT RATIOS AT THE EXPERIMENTAL AND INTERPOLATED RADII FOR THE USNS HAYES T-AGOR 16 WITH BOW FOIL AT 10 KNOTS REPRESENTED BY MODEL 5285

WAKE ANALYSIS
PROGRAM VERSION OF 11/01/79

USS HAYES T-AGOR 16 WAKE SURVEY 11 23 83 EXP 20 10 KNOTS 21.77 FT
PROPELLER DIAMETER = 12.00 FEET JV = .703

HARMONIC ANALYSES OF TANGENTIAL VELOCITY COMPONENT RATIOS (VT/V)

HARMONIC =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RADIUS = .334																
AMPLITUDE =	.117	.061	.021	.013	.007	.007	.006	.003	.002	.002	.002	.001	.000	.002	.001	.001
PHASE ANGLE =	176.6	165.3	347.8	152.5	346.5	159.2	324.3	81.1	34.5	144.3	307.1	48.8	346.1	161.4	260.2	46.7
RADIUS = .446																
AMPLITUDE =	.152	.061	.006	.015	.007	.007	.004	.003	.002	.001	.001	.001	.001	.001	.001	.001
PHASE ANGLE =	175.9	159.6	61.0	165.0	325.9	151.7	322.5	139.2	318.1	110.2	319.5	102.5	334.4	63.6	166.9	217.5
RADIUS = .613																
AMPLITUDE =	.145	.058	.025	.018	.004	.010	.004	.009	.003	.006	.003	.005	.002	.004	.002	.002
PHASE ANGLE =	174.9	163.7	140.8	164.0	86.2	142.0	350.8	128.7	331.5	109.0	315.1	92.0	290.8	72.1	294.0	46.9
RADIUS = .780																
AMPLITUDE =	.126	.053	.034	.022	.011	.006	.004	.007	.004	.006	.004	.005	.004	.004	.004	.003
PHASE ANGLE =	175.1	176.7	159.4	174.9	107.0	157.1	69.1	156.1	37.8	144.4	15.5	133.0	350.5	125.5	338.0	132.4
RADIUS = .949																
AMPLITUDE =	.112	.052	.033	.021	.010	.010	.006	.008	.004	.006	.002	.005	.002	.005	.002	.004
PHASE ANGLE =	179.4	181.9	160.6	180.0	111.1	176.6	91.6	165.8	39.4	166.6	21.9	159.5	352.9	142.3	333.2	141.4
RADIUS = 1.115																
AMPLITUDE =	.104	.043	.029	.014	.008	.008	.006	.006	.005	.006	.005	.005	.004	.005	.003	.005
PHASE ANGLE =	189.3	172.5	190.2	159.6	208.1	133.5	204.1	121.4	213.9	119.2	215.4	97.8	223.2	82.2	228.3	62.6

WAKE ANALYSIS
PROGRAM VERSION OF 11/01/79

USS HAYES T-AGOR 16 WAKE SURVEY 11 23 83 EXP 20 10 KNOTS 21.77 FT E.K.
PROPELLER DIAMETER = 12.00 FEET JV = .703

HARMONIC ANALYSES OF TANGENTIAL VELOCITY COMPONENT RATIOS (VT/V)

HARMONIC =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RADIUS = .202																
AMPLITUDE =	.035	.063	.047	.013	.011	.008	.009	.011	.006	.006	.004	.003	.001	.005	.005	.009
PHASE ANGLE =	180.8	180.5	335.5	120.1	51.7	162.9	333.9	68.7	63.1	137.4	299.4	44.8	245.9	155.5	298.1	42.5
RADIUS = .400																
AMPLITUDE =	.141	.061	.010	.014	.007	.007	.004	.002	.001	.001	.001	.001	.000	.000	.001	.001
PHASE ANGLE =	176.1	151.1	10.2	161.5	330.2	155.0	321.6	118.5	336.9	134.2	314.9	90.0	348.1	129.5	181.6	215.7
RADIUS = .500																
AMPLITUDE =	.151	.060	.012	.016	.004	.009	.004	.006	.003	.003	.002	.003	.001	.002	.001	.000
PHASE ANGLE =	175.4	160.1	117.0	163.0	347.6	145.2	329.9	128.0	317.4	103.3	307.4	87.1	284.6	60.2	232.6	12.9
RADIUS = .600																
AMPLITUDE =	.146	.058	.024	.018	.004	.010	.004	.009	.003	.006	.003	.005	.002	.003	.002	.002
PHASE ANGLE =	175.0	163.1	139.2	163.6	80.8	142.0	347.5	128.0	328.8	138.0	312.8	90.7	287.9	70.0	289.5	43.8
RADIUS = .700																
AMPLITUDE =	.135	.054	.030	.021	.008	.007	.003	.007	.004	.006	.003	.005	.003	.004	.003	.002
PHASE ANGLE =	174.6	171.2	153.9	176.8	102.5	146.4	41.2	143.7	19.2	128.4	358.5	115.9	338.8	106.7	330.8	111.6
RADIUS = .800																
AMPLITUDE =	.124	.053	.034	.022	.011	.007	.005	.007	.005	.006	.004	.005	.004	.004	.004	.004
PHASE ANGLE =	175.3	173.0	158.4	176.5	105.7	164.5	71.8	159.8	37.6	151.0	17.9	140.6	353.5	131.7	340.0	136.2
RADIUS = .900																
AMPLITUDE =	.116	.053	.034	.022	.011	.009	.006	.008	.005	.006	.003	.005	.003	.005	.003	.004
PHASE ANGLE =	177.6	191.7	157.9	180.4	106.3	177.6	83.2	167.3	39.5	167.5	22.7	160.3	359.0	144.7	340.8	146.6
RADIUS = .950																
AMPLITUDE =	.112	.052	.033	.021	.010	.010	.006	.008	.004	.006	.002	.005	.002	.005	.002	.004
PHASE ANGLE =	179.5	181.9	160.7	180.0	111.4	176.5	92.1	165.6	39.4	158.5	21.7	159.3	352.3	142.1	332.7	141.1
RADIUS = 1.000																
AMPLITUDE =	.109	.050	.032	.019	.008	.009	.004	.007	.002	.006	.001	.004	.001	.004	.002	.003
PHASE ANGLE =	181.9	190.4	165.0	177.7	123.2	171.3	109.9	159.9	43.2	159.4	8.5	150.6	317.3	132.8	309.7	126.7

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

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